

PROBING THE



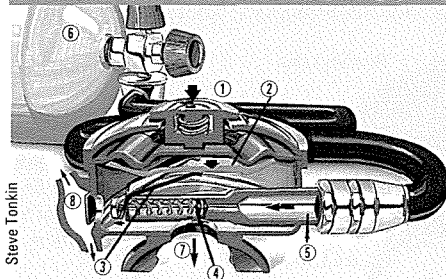
Rex Features

SPECIALIST DIVING EQUIPMENT can take Man to greater depths than ever before – and in relative safety. Even the idea of an entire city beneath the waves is by no means beyond the realms of possibility.

A diver must keep warm to stay alert. If the body gets too cold, concentration wanders and more air is used up. So divers often wear wet suits made of foam neoprene (synthetic rubber) – even in quite warm waters.

A small quantity of water seeps into the suit and becomes trapped between the material and the diver's skin. The water is quickly warmed by the heat of the body, and air bubbles in the neoprene act as a heat insulator. It is like swimming in a lukewarm bath!

HOW AN AQUALUNG WORKS



Steve Tonkin

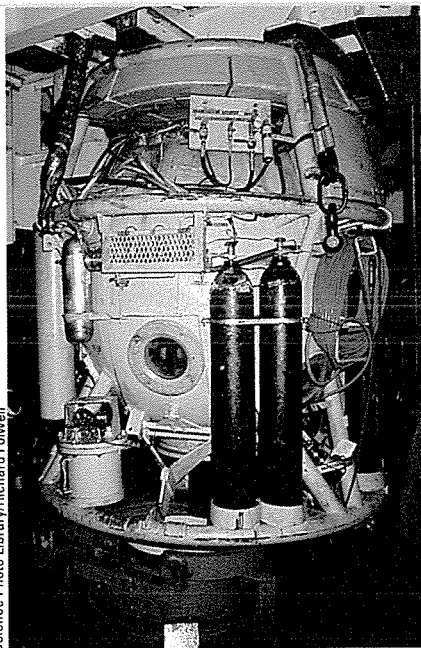
Water enters the demand valve (1) and presses on a rubber diaphragm (2). An attached lever (3) controls a valve (4) to admit air (5) from the cylinder (6). This arrangement keeps the air supply to the mouthpiece (7) at the right pressure – the same pressure as the surrounding water. Used air is expelled through a valve at the side (8).



Patrick Baker/Bruce Coleman Ltd

DEPTHS





A pressurized North Sea diving bell normally receives air through the umbilical when submerged. For use in emergencies, the bell carries air cylinders on the outside.

cavities in the head are squeezed. And it would be impossible to breathe through a snorkel tube two metres long because the lungs could not expand against the extra pressure under water. This is why divers use a compressed air supply with a device that regulates the pressure to match that of the surrounding water.

The most common form of scuba (self-contained underwater breathing apparatus) is the aqualung. It allows a diver to swim to depths of 50 metres for up to an hour.

Cylinders of compressed air (at a pressure over 200 times that of the air around us) are carried on the back. A flexible hose connects the cylinders to a mouthpiece. Whenever the diver inhales, a device called a demand valve allows air to flow from one of the cylinders.

The equipment may look heavy and clumsy, but in the water it is almost weightless and the diver retains freedom of movement.

Avoiding the bends

As the diver goes deeper, the water pressure and the pressure of the air breathed become greater. If this air pressure is released too quickly by the diver surfacing too fast, the expanding air may damage the lungs and form bubbles in the blood. This effect, called air embolism, restricts the blood flow and may cause injury or even death.

Fast surfacing may also cause decompression sickness, usually



called 'the bends'. This occurs when bubbles of nitrogen gas from the air form in the blood, and is as dangerous as air embolism. To avoid these dangers, the rate of decompression (the change from high- to low-pressure conditions) must be carefully controlled.

The narks

Another problem of working at great depths is that breathing the high-pressure air mixture of nitrogen and oxygen could result in nitrogen narcosis (the 'narks') — a sort of drunkenness. Nitrogen makes up four-fifths of the air we breathe, and too much could be absorbed by the blood under these conditions. The nitrogen acts like a drug, causing muddled thinking, disorientation and, sometimes, panic.

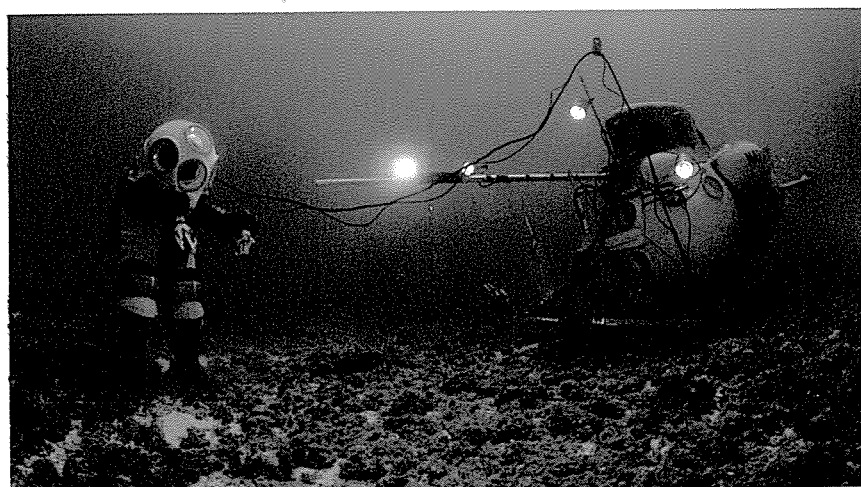
To avoid this, the nitrogen is replaced by helium gas. The helium-oxygen mixture is known as heliox. Helium has the comical side-effect of making even the gruffest voice sound like Donald Duck, so electronic speech decoders are used to understand the diver's words.

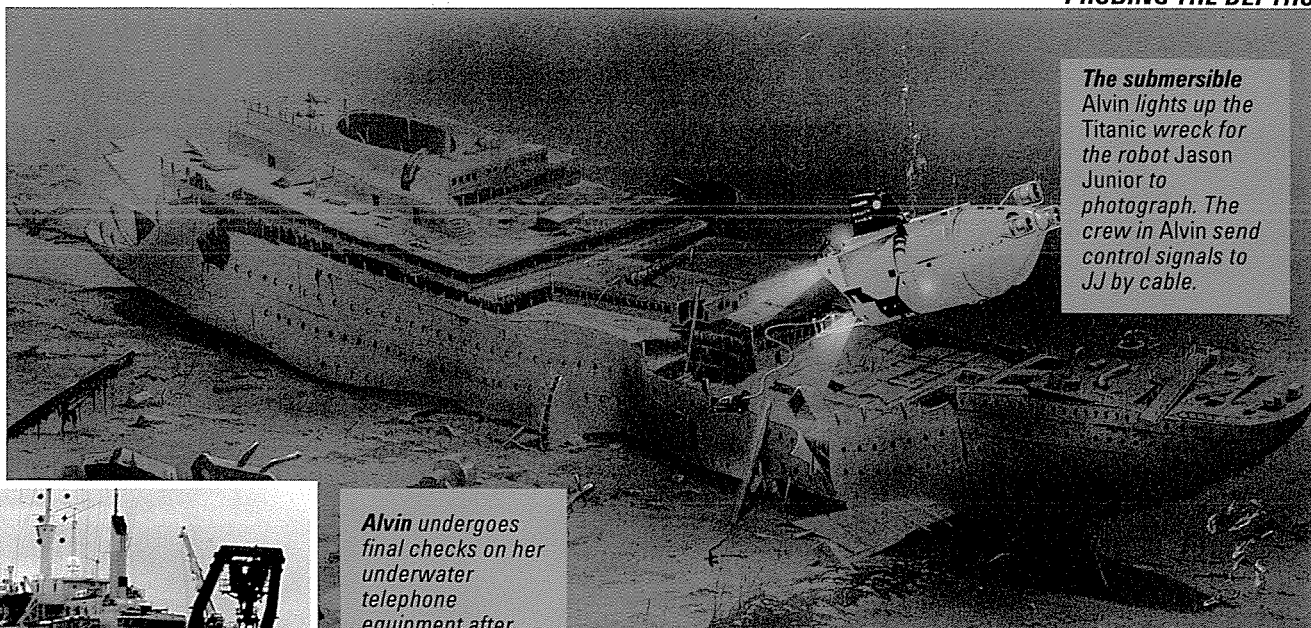
Because the air is so highly compressed, far more is used for each breath. A cylinder that lasts for 30 minutes at 10 metres would not last

ATMOSPHERIC DIVING SUIT



Like an astronaut exploring the Moon's surface, a diver in an atmospheric diving suit searches the sea bed, fully protected from his hostile surroundings.





The submersible Alvin lights up the Titanic wreck for the robot Jason Junior to photograph. The crew in Alvin send control signals to JJ by cable.



Alvin undergoes final checks on her underwater telephone equipment after being lowered from the frame at the back of Atlantis II.

EXPLORING THE TITANIC

Disaster struck in 1912, when SS *Titanic* hit an iceberg and sank. Some 1,500 people perished in the disaster, only one-third of those aboard living to tell the tale. The luxury liner lay undisturbed on the sea bed until its discovery in 1985. One year later, the ship *Atlantis II* took a team to explore the wreck using the manned submersible *Alvin*. Jason Junior, an underwater robot affectionately known as 'JJ', probed the wreck to photograph its interior.

Bill Donohoe



The deck of the Titanic has a mystical eerie appearance after a lifetime on the sea bed. Corrosion and plant life colour the rusting steel structure.

three minutes at 200 metres. Although deep-sea divers carry a cylinder in case of emergency, their main air supply comes through a tube from the surface.

As well as air, hot water can be supplied to heat the diver's suit and a telephone link provided for communication with the surface.

Saturation diving

After a few minutes at 200 metres, a diver would need hours of decompression. So where a diver is required to spend a long time in very deep waters, it is more practical – and safer – to employ saturation diving. This means that the body becomes saturated with breathing gas at high pressure until no more can be absorbed. When he is not working, the diver lives in a sealed chamber, which has been 'blown down' to a pressure corresponding to the working depth.

To enter the water, the diver transfers – still under pressure – to a diving bell. This bell is detached from the chamber and lowered to the seabed or working site, where the diver leaves through a bottom hatch. After a period of work, the diver re-enters the bell and is

hoisted back to the chamber.

Divers can work like this for weeks or even months. Decompression does not begin until the end of the whole project and can take several days to complete.

One outfit that has overcome the problem of water pressure and decompression is the 'atmospheric' diving suit. The JIM – named after Jim Jarratt, the mechanic who tested the prototype in the 1930s – is capable of going to depths of over 500 metres. Inside, the diver remains safe and dry, breathing air at normal atmospheric pressure.

The suit has limbs with watertight flexible joints that allow the diver to move and work quite freely. It is just like an underwater observation chamber with arms and legs.

Submersibles are another alternative for deeper exploration. These miniature submarines are capable of carrying a small, but expert crew to depths of 4,000 metres.

Submersibles are taken to the work site on a support ship and launched – usually over the stern – from a large gantry. Mobile submersibles have thrusters (ducted propellers), which are turned by battery-powered electric motors.

These submersibles cover short distances at only a few knots.

Submersibles can also be operated from the surface. A remotely-operated vehicle (ROV) usually has a frame that supports motors and thrusters, buoyancy devices, and masses of manipulating and sensing equipment – effectively the eyes, ears and hands of the vehicle.

This type of underwater robot is tethered to the surface by an umbilical cable that carries power, navigational information, command signals and television pictures from the watertight cameras on board. The operator simply controls the ROV using a joystick.

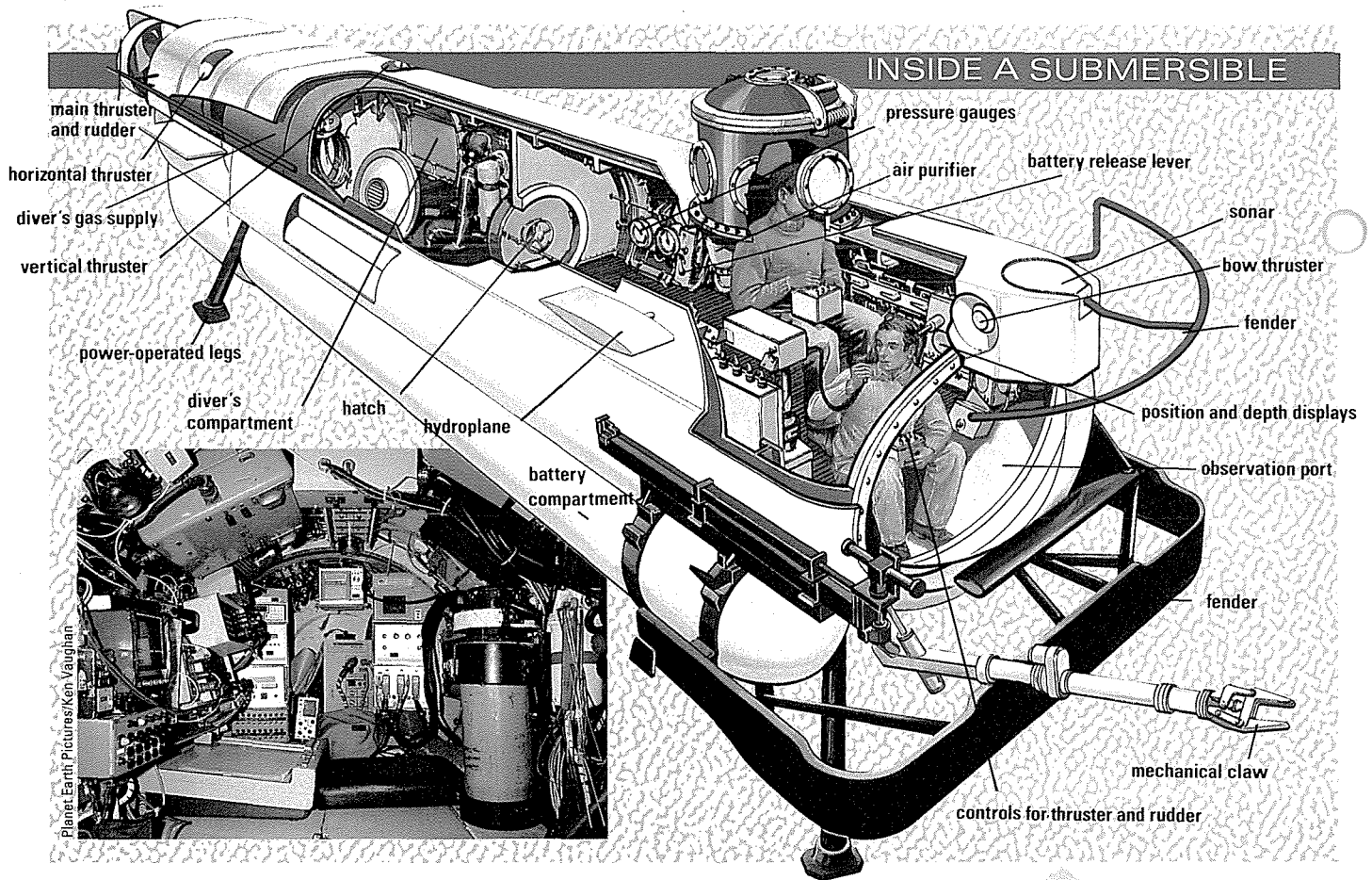
Deep water work

The ROV's lifeline – the umbilical – becomes its undoing for deep-water work. Despite the use of ultra-slim optical-fibre cables for video and command links, umbilicals are quite heavy because they also carry high-current electrical supplies to the propulsion motors. Beyond depths of 2,000 metres, the bulk and weight of the umbilical becomes unmanageable.

However, in 1985, 180 km off south-west Ireland, a Scarab II ROV



INSIDE A SUBMERSIBLE



located the wreckage of an Air India jumbo jet. Later, vital clues were recovered from the sea-bed at a depth of over 2,000 metres in one of the most ambitious ROV operations ever undertaken.

Perhaps the most futuristic submersible is *l'Argyronete* planned for the French 'Saga' project, to locate oil and gas under the sea-bed beneath the polar ice-caps. The vehi-

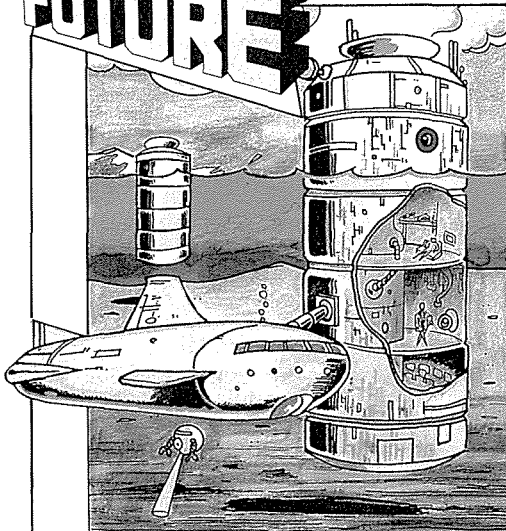
cle will carry a crew of six, and a team of divers operating from a pressurized 'lock-out' chamber. But travelling under ice-caps means the vessel will be away from its support ship for a day or more, ruling out rechargeable batteries for propulsion. Instead, Stirling engines, which need no exhaust, or compact nuclear reactors, may be used.

Another pioneering idea is plea-

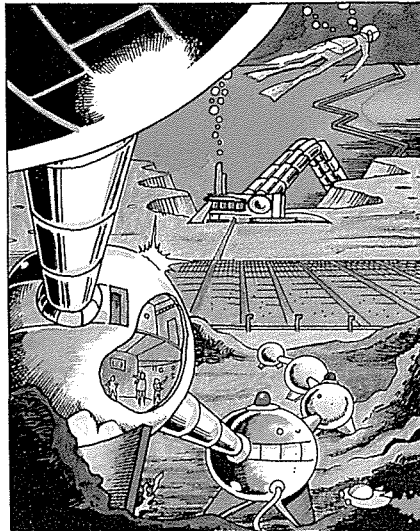
A diver prepares to leave his submersible through a hatch. Control and monitoring equipment inside a British Oceanics submersible (inset).

sure cruising in submersibles. In the Caribbean, up to 50 passengers can be taken on hour-long dives to 70 metres. An ROV 'flying eyeball', shows close-ups of marine life.

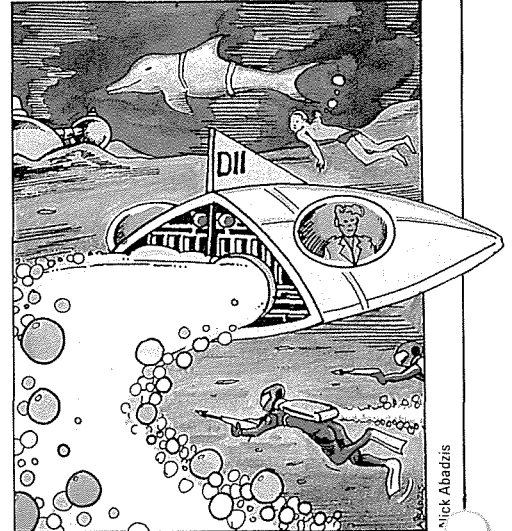
INTO THE FUTURE



▲ One day floating capsules may provide homes for some of the world's expanding population. Powerful engines will keep the capsules in position.

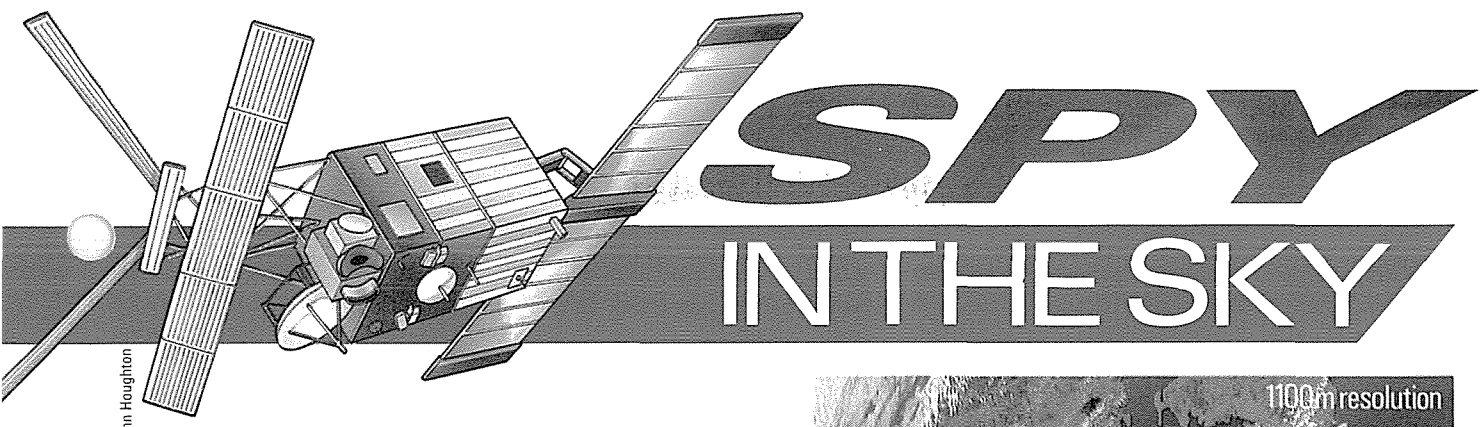


▲ People will work in factory units, linked to one another by sealed corridors. Hatches will allow divers access to the outside for maintenance work.



▲ Submersible taxis will take workers to factories. Trained dolphins may act as postmen, with armed police patrols providing protection against predators.





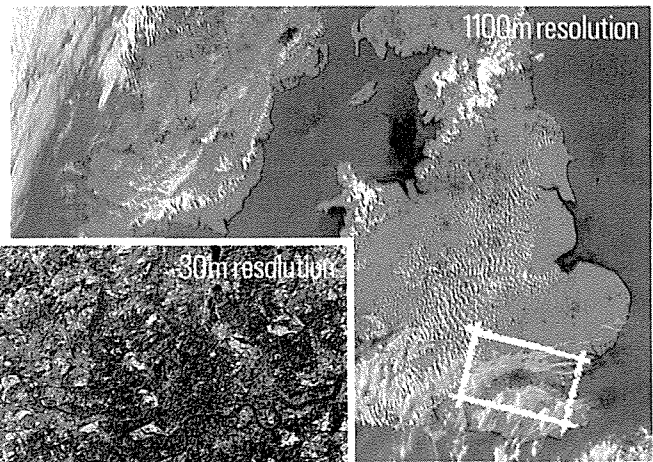
John Houghton

- Q NAVIGATION
- Q WATCHFUL EYES
- Q WEATHER PREDICTION

SOMEWHERE IN SECRET FILES in the United States and the CIS are pictures that, if magnified, would show your house, your family's car, and perhaps even you, walking down the street.

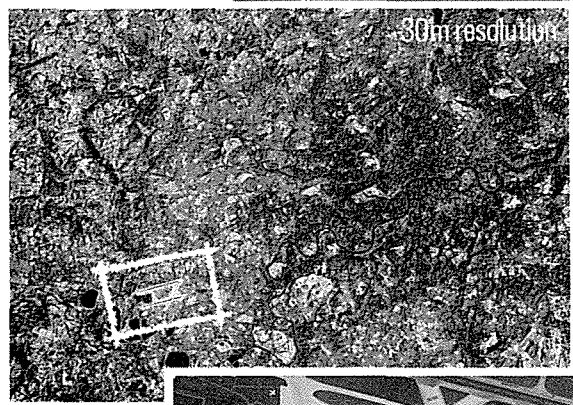
They were taken by spy satellites, hovering high above Earth's atmosphere, fitted with super-powerful cameras.

Apart from the dramatic pictures that these 'eyes in the sky' can give, they also provide other, vital data. Other spacecraft circling the Earth monitor the weather or



1100m resolution

Daily Telegraph Colour Library



30m resolution

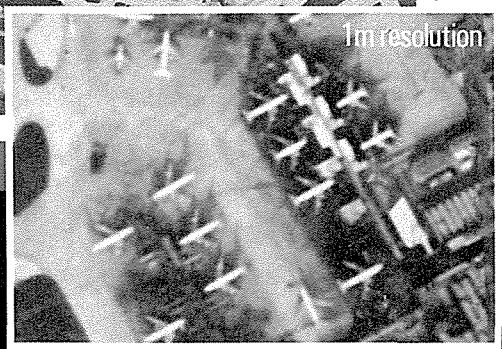
Salamander

Satellites orbiting Earth can produce photos of remarkable quality. (From the top) At 1100 metres resolution – a natural colour shot of Southern Britain. At 30 metres – an infra-red image of land use. Closing in further to 5 metres resolution, the layout of Heathrow Airport becomes apparent. At 1 metre resolution, individual planes can be identified on the tarmac.



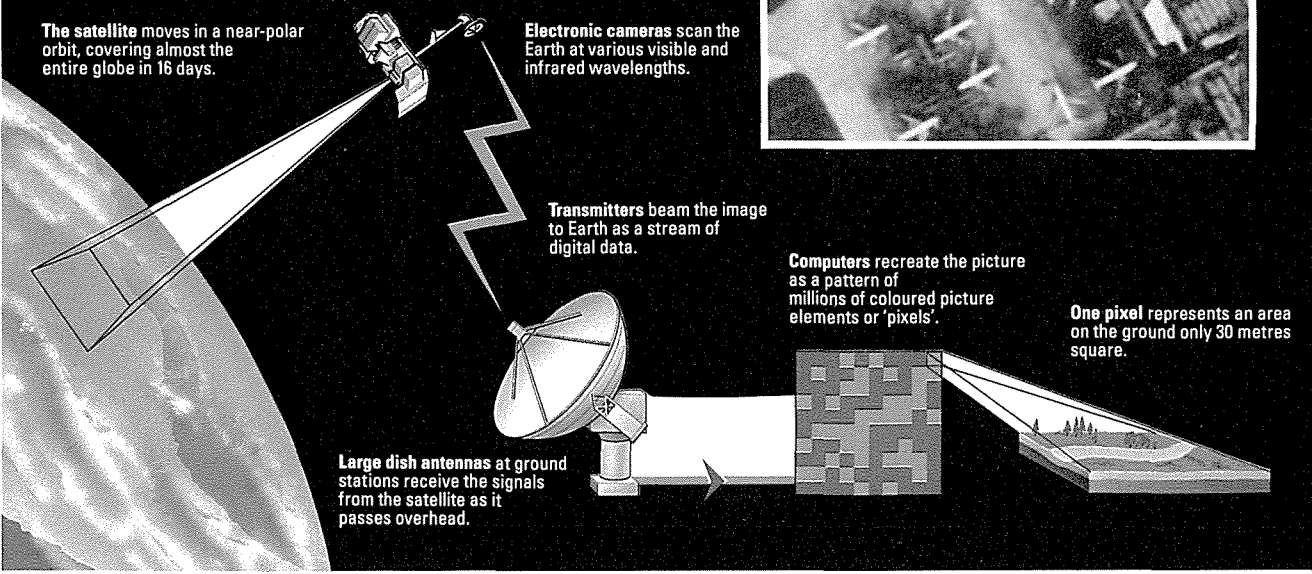
5m resolution

Heathrow Airport Ltd

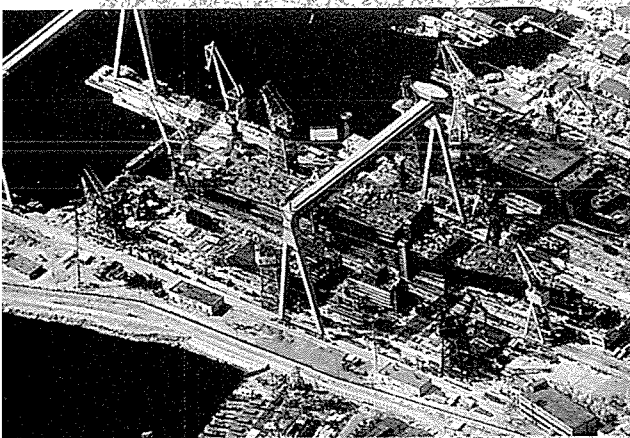


1m resolution

MAKING A LANDSAT PICTURE



Berry Fallon Design



Few things can be kept secret from the American KH-11 spy satellite that took this picture. It shows the 75,000-tonne nuclear aircraft carrier *Leonid Brezhnev* being built at a Soviet port on the Black Sea. Though the picture looks as detailed as if it were taken from a plane, the satellite was actually 250 km above the Earth's surface. It can photograph a detail as small as 30 cm across.

Associated Press

survey the surface for mineral wealth. Everything on our planet has its own special way of reflecting, transmitting and absorbing light. So from space a field of wheat, for instance, looks different from a field of maize, and an out-crop of iron ore looks different from one of coal.

Getting the data back

Satellites gather data with a variety of instruments — photographic cameras, TV cameras, infra-red detectors and so on. TV and radio signals are beamed down to receiving stations on the ground. Capsules containing exposed film can be returned to Earth by parachute. Or the film can be scanned electronically, and the resulting signal transmitted to Earth.

Using computers, detailed colour pictures can then be built up from the spacecraft information, allowing scientists to spot crop diseases and forest fires, search for valuable minerals, follow the movement of oil slicks that threaten to pollute beaches, and even watch the migration of animal herds.



A Landsat infra-red image of New York City. The Hudson River runs to the top of the image; Kennedy Airport is the light-coloured rectangular complex to the right.

Earth Satellite Corp./SPL



CATCHING FILM IN MID-AIR

Satellite film can be returned to Earth in a capsule. To avoid losing it in water or inaccessible terrain, a C-130 grabs the capsule in mid-air. Once snagged, the parachute and capsule are winched in.

Satellites also provide early warnings of approaching blizzards, or of hurricanes as they develop out at sea and then move in toward land.

Steering by satellite

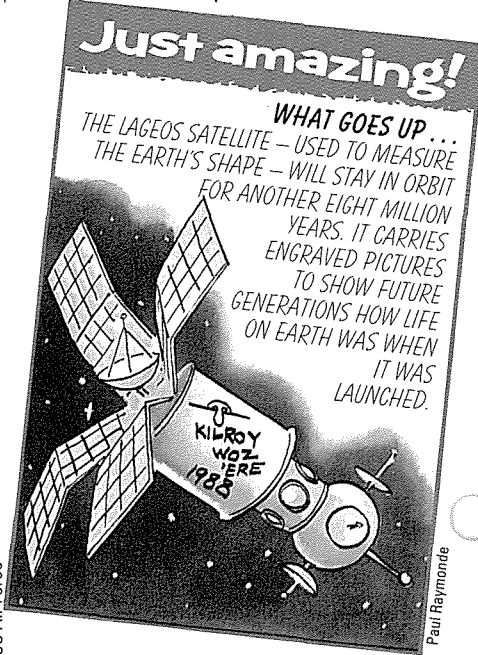
Long ago, sailors used to set their ship's course according to the position of the Sun and stars. Today, navigation satellites act as artificial 'stars' by which pilots on the sea or in the air can find precisely where they are at any instant.

Navigation satellites work by sending down radio signals that give the spacecraft's exact location in space at a given time. Ships and aeroplanes need only pick up the signals from three separate satellites to be able to work out their own position. All the necessary calculations are done swiftly by a miniature computer on the ship or aeroplane.

Even small sailing boats equipped with a proper receiver, can make use of satellite navigation. And the next step will be to develop a similar system that can work in cars and other road transport. Early in the next century it should be possible to keep track of your car's position to within 20 or 30 metres, and for a computer display inside the car to show the best route to follow to reach a particular destination.

Mission to Earth

The world's major space agencies have agreed to increase their co-operation in observing Earth from space. Information from orbit will show clearly what effect the human race is having on its environment. It will allow each nation to make better use of its resources and to be warned of any impending natural or man-made disasters. Increasingly, our eyes in the sky will give us a fresh view of the Earth and the knowledge we need to take better care of our home planet.



US Air Force



TELESCOPES

FOR TOMORROW

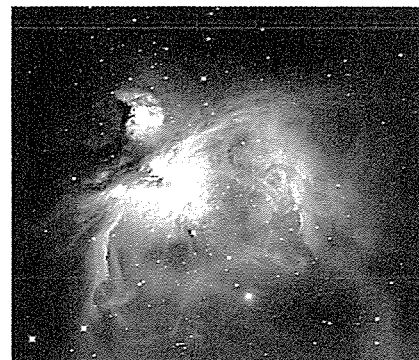
OVER THE LAST FEW DECADES, astronomers have discovered an astonishing 'zoo' of new objects in space. There are tiny dead stars, called pulsars, spinning round dizzily and sending out narrow beams of radiation that sweep round like the beams from a lighthouse. There are blazing whirlpools of matter swirling around monstrous black holes. And there are galaxies colliding, massive stars exploding, and planets being born.

It is thanks to the most recently developed tools of astronomy that these amazing sights have been brought into clear view. By building bigger, better optical telescopes,

scientists have learned very much more about the Universe as it looks in ordinary light. But just as importantly, they have extended their vision with instruments that can 'see' radio waves, x-rays, infra-red waves, and other types of invisible radiation.

All the biggest optical telescopes in the world today use a curved mirror to gather and focus the light from distant objects. The light may be focused on to film, building up a detailed image over a period of hours. Or it may be collected by very sensitive electronic detectors that amplify even the tiniest trickle of light from a far-away object.

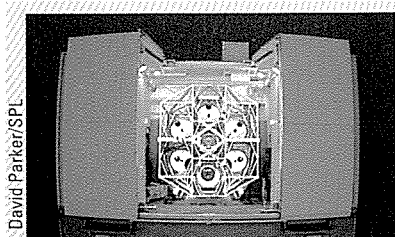
The Hubble Space Telescope, launched by the Space Shuttle in



Ronald Royer/SPL

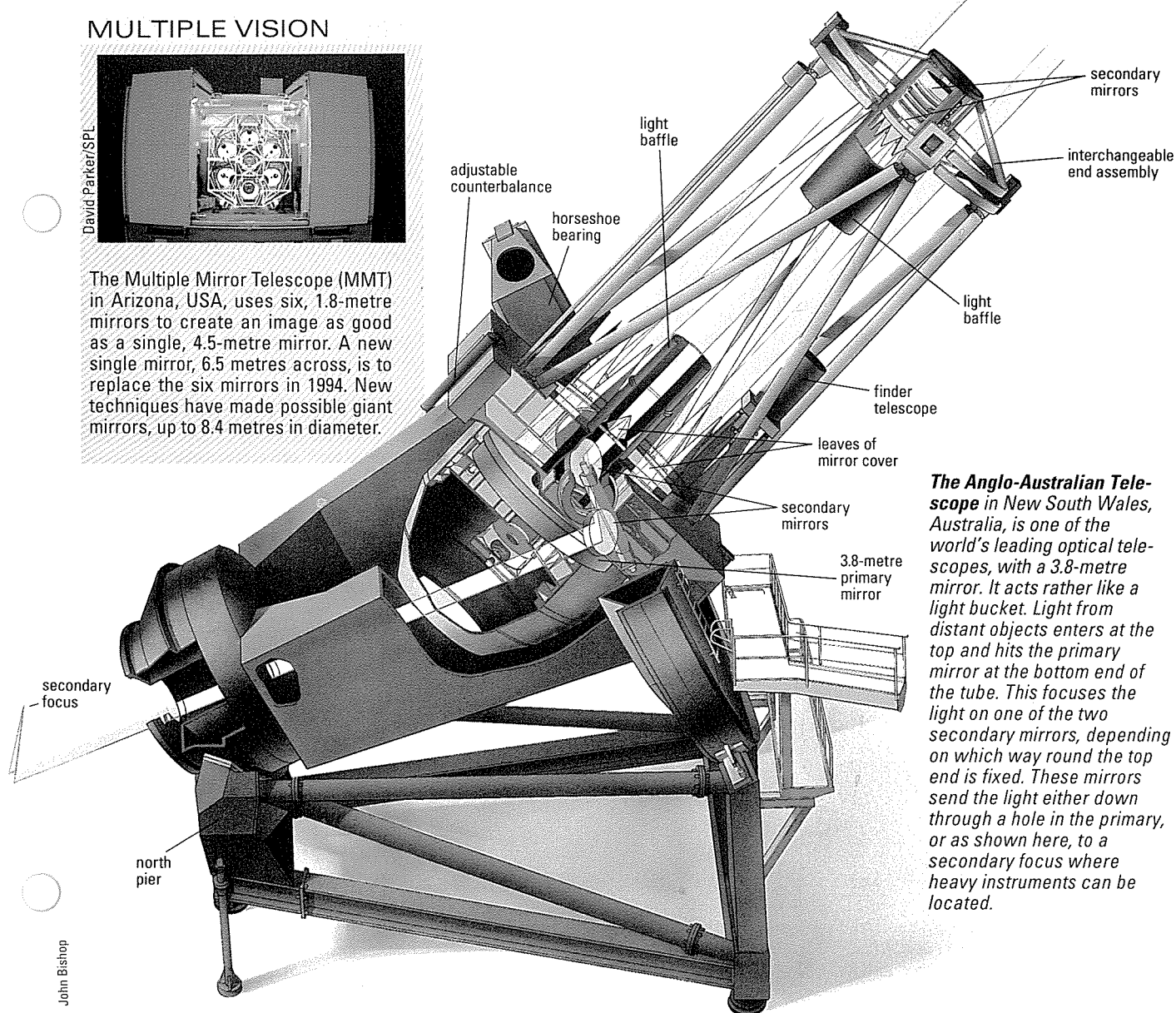
Orion Nebula, a glowing cloud of gas, taken using a long exposure photograph. This builds up the light from the faintest parts, making them easily visible.

MULTIPLE VISION



David Parker/SPL

The Multiple Mirror Telescope (MMT) in Arizona, USA, uses six, 1.8-metre mirrors to create an image as good as a single, 4.5-metre mirror. A new single mirror, 6.5 metres across, is to replace the six mirrors in 1994. New techniques have made possible giant mirrors, up to 8.4 metres in diameter.



The Anglo-Australian Telescope in New South Wales, Australia, is one of the world's leading optical telescopes, with a 3.8-metre mirror. It acts rather like a light bucket. Light from distant objects enters at the top and hits the primary mirror at the bottom end of the tube. This focuses the light on one of the two secondary mirrors, depending on which way round the top end is fixed. These mirrors send the light either down through a hole in the primary, or as shown here, to a secondary focus where heavy instruments can be located.

John Bishop



April 1990, is the first large optical telescope in space. Its 2.4-metre mirror gives the best views of the Universe yet, as it does not have to observe through Earth's polluted atmosphere.

A major new 'window' on the sky opened up when it was found that

radio-emitting objects in space, the observations from widely spaced radio telescopes are combined to yield a much more finely detailed view of the radio sky. Radio telescopes in different continents can be linked in this way.

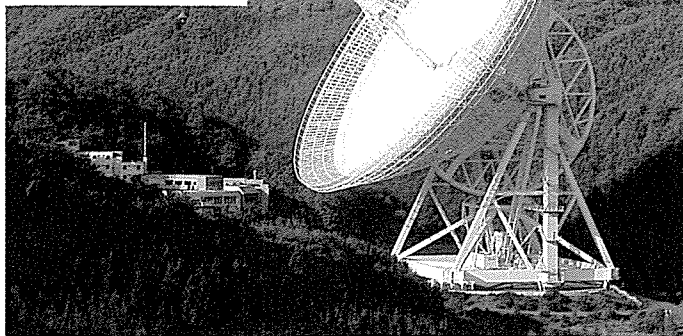


Heart of the galaxy

Radio astronomers have been able, among other things, to peer beyond the dust that hides the mysterious core of our Galaxy from the view of the optical astronomer.



The giant dish of Effelsberg radio telescope in Germany. But at 100 metres, it is almost dwarfed by the 300 metre dish set in a natural hollow near Arecibo in Puerto Rico (inset).



Max-Planck-Institut für Radio-Astronomie/SPL

radio waves arrive at the Earth from space. Since radio wavelengths range from about a thousand to many millions of times those of light waves, the collecting dish of a radio telescope has to be much wider than the mirror of an optical telescope. Only in this way can astronomers distinguish reasonably fine detail in the objects they study.

To focus even more sharply on

Most kinds of radiation, other than ordinary light and radio waves, are prevented from reaching the ground by the Earth's atmosphere. To detect and decode these cosmic messages, special instruments have to be sent into space aboard orbiting satellites.

Spaceborne x-ray detectors, for instance, have recently given us glimpses of extremely violent parts

of the Universe. One especially powerful source of x-rays, known as Cygnus X-1, is almost certainly due to fantastically hot matter plunging into a star-sized black hole, the remnant of a star that blew up as a supernova.



The infra-red sky

Observations made by the Infra-red Astronomical Satellite, IRAS, have given astronomers their first clear picture of the infra-red sky. (Infra-red radiation has wavelengths longer than visible light. Heat radiation is one kind of infra-red light). IRAS has found glowing rings of material circling some nearby stars, such as Vega and Fomalhaut. Within these dusty rings, some astronomers suspect, new systems of planets are being formed.

Just amazing!

CANDLE POWER

A SET OF 36 MIRRORS COMBINE TO MAKE THE WORLD'S BIGGEST OPTICAL TELESCOPE, 10 METRES ACROSS, ON HAWAII. KNOWN AS THE KECK TELESCOPE, IT IS POWERFUL ENOUGH TO PICK UP THE LIGHT OF A SINGLE CANDLE 70,000 KM AWAY.



Paul Raymond

INTO THE FUTURE

PROJECT CYCLOPS



Alan Burrows

▲ As 'electronic smog' – stray radio and TV signals – becomes worse on Earth, radio astronomers may be forced to take their equipment into space.

▲ Radio observatories could be built on the far side of the Moon, the only place in the solar system shielded from Earth's electromagnetic interference.

▲ An array of hundreds of radio telescopes, called Project Cyclops, could probe the Universe to enormous distances, or pick up messages from alien civilizations.



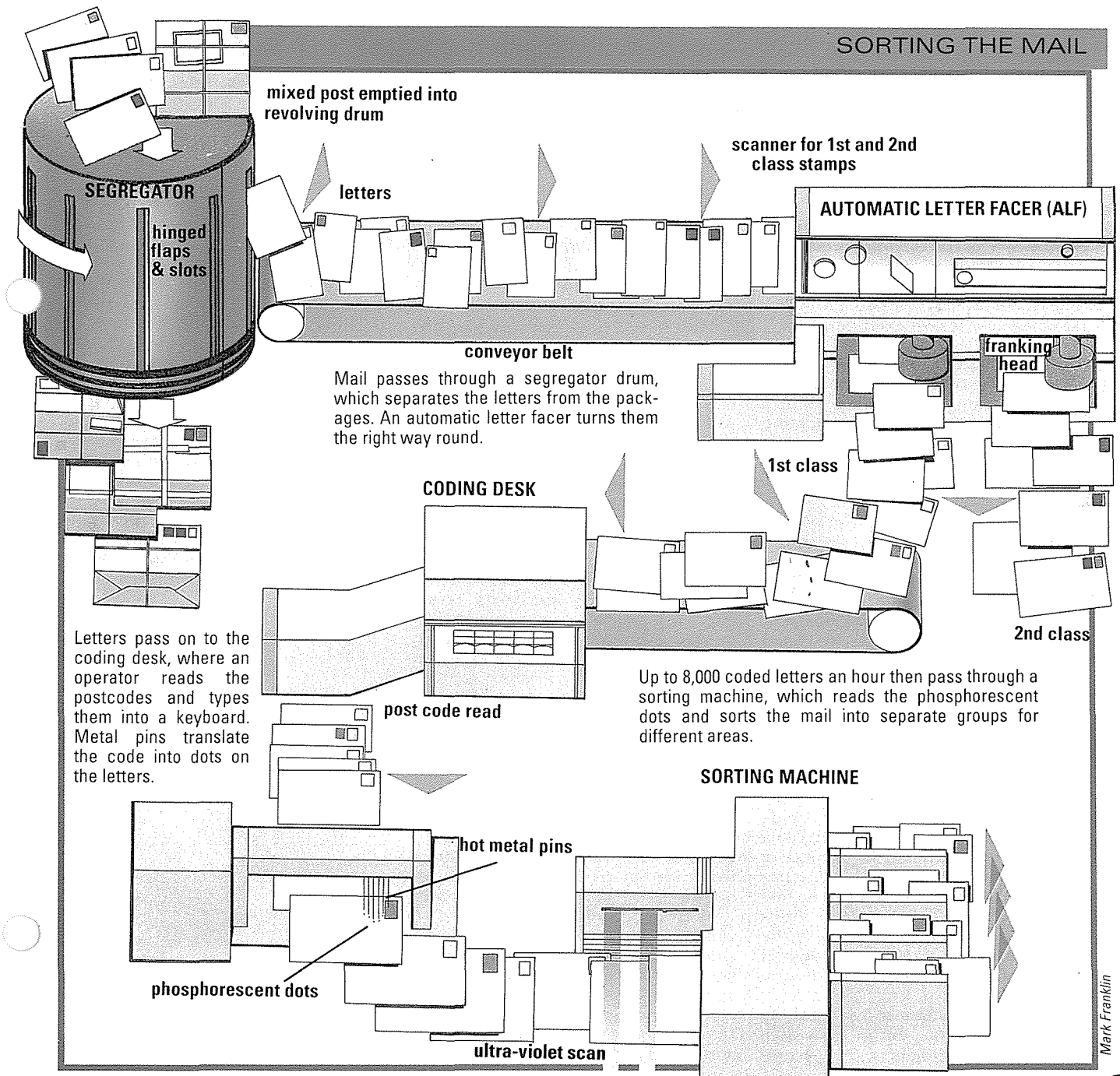
ELECTRONIC MAIL

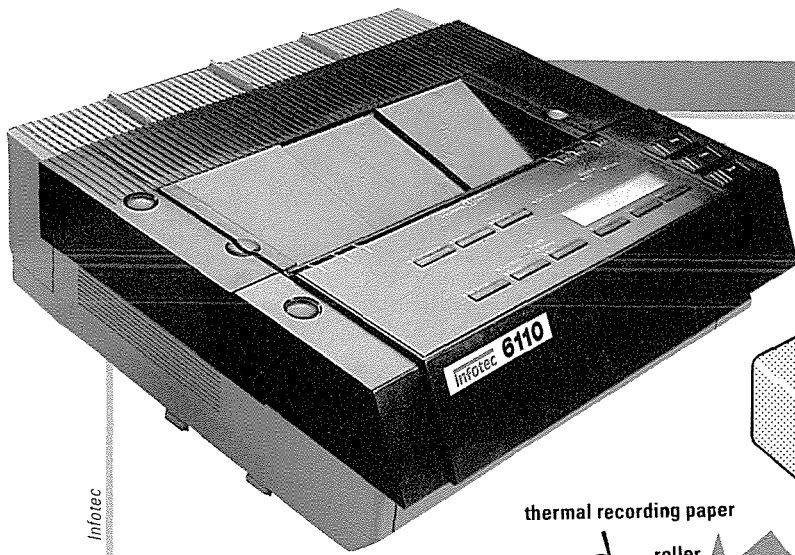
WHEN SCIENCE-FICTION writer Arthur C. Clarke began work on the film '2010: Odyssey Two' he faced a big obstacle. Clarke lives in Sri Lanka and hates to travel. He had to work with the film's director and screenwriter, Peter Hyams, based in Los Angeles.

How could these two men collaborate closely when they were based nearly 20,000 km apart?

Ordinary mail would have been hopelessly slow. The time difference, and the busy schedules of the men made phone calls impractical. But Clarke and Hyams solved their communications problem by using electronic mail, or e-mail — a remark-

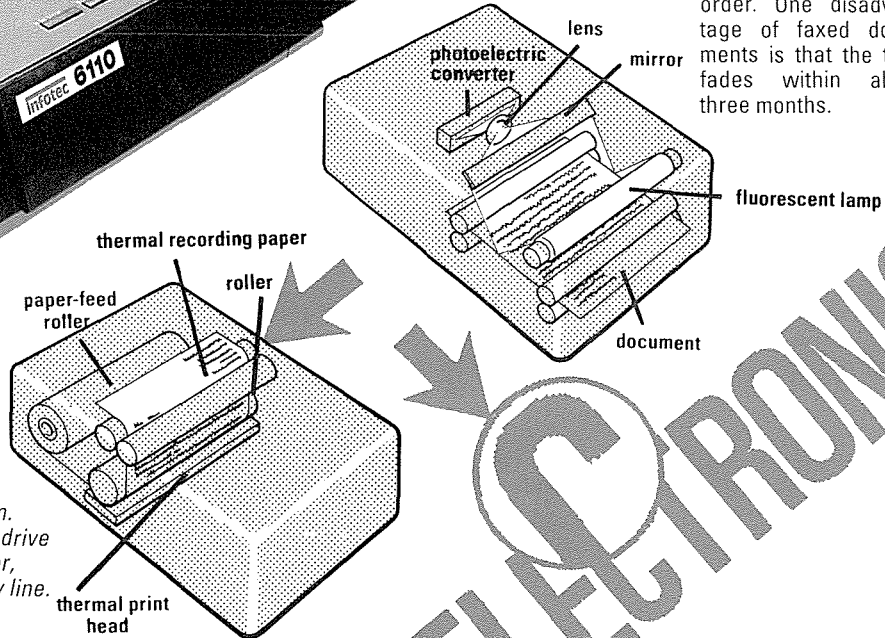
able way of sending messages by computer. A message typed by one of the men on his personal computer was sent over the international phone network and stored in a large computer in the other country. The other man then used his own personal computer to 'read' this message, using a local phone link at any convenient time.





Infotec

A facsimile machine, or fax, changes the image on a document into a series of electrical pulses. Light from the paper is focused on to a light-sensitive cell, which changes light variations into pulses that travel through the phone system. The receiving fax uses these to drive a thermal or electrostatic printer, which copies the original line by line.



While new methods of communicating are partly taking over from conventional mail, the postal agencies are bringing in modern technology to speed up their service. Automatic sorting is one example.

Coding the post

At a letter-sorting office each incoming envelope is marked with a machine-readable code indicating where it is to be sent. The code consists of a pattern of phosphor dots that glow when invisible ultraviolet light is shone on them.

An operator usually reads each address, as a machine presents the envelope to him, and types out the code. But in some sorting offices those letters that have typewritten addresses are sent to machines that can read printed characters. These machines then mark on the phosphor dot patterns, and sorting machines route the letter to the next stage of its journey.

Instant messages

Even without using computers, information can be 'posted' today almost instantly between places that may be very far apart. Any document, whether it is printed or handwritten text, or even an illustration, can be sent over the phone line via facsimile machines. Telex machines (teleprinters) also use the phone network. These transmit typed messages rapidly from one place to another.

Many companies now provide their employees with individual computer terminals, or 'work-

stations', so they can pass information instantly and easily from desk to desk and from office to office, saving the company both time and money.

Methods for receiving electronic messages over the telephone lines are available in the home, even to people who do not own computers or fax machines. A subscriber to a 'viewdata' service uses an ordinary TV set. He can call up any one of hundreds of thousands of 'pages' of information that are regularly added to and updated.

Viewdata

Weather forecasts, road traffic reports, aircraft departures and arrivals, sports results and news, financial information, entertainments guides and many other information services can all be provided on viewdata.

All this information is stored in the memory of a powerful central computer. It can be contacted by any subscriber to the viewdata service simply by dialling its telephone number on a keypad. An index displayed on the television screen shows the subscriber which buttons to press in order to obtain the information that he or she requires.

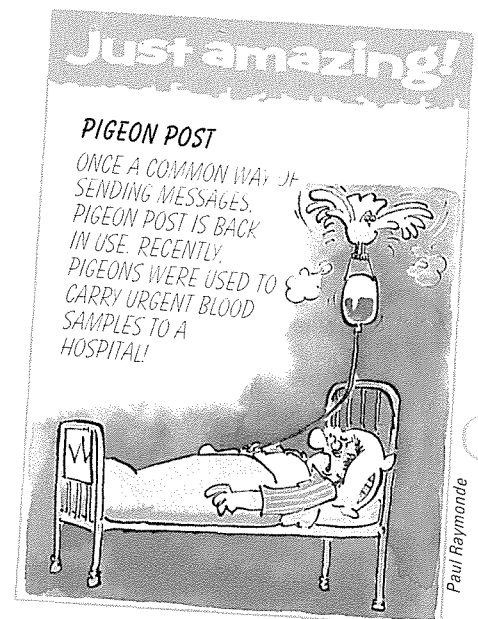
In Britain, British Telecom run a viewdata service called Prestel. Besides obtaining information, subscribers with a suitable personal computer can use Prestel's electronic mail service to leave messages for other subscribers in the main computer's memory.

Fax machines are now an invaluable addition to the modern office, but they are also becoming a common sight in the high street. Many printing and photocopying shops act as fax bureaux, sending and receiving private documents to order. One disadvantage of faxed documents is that the type fades within about three months.

E-mail works well for transmitting typed messages. But when the information to be sent is in ordinary handwriting, or contains a mixture of text and illustrations, a facsimile, or fax machine can be used to transmit it through the telephone system to another fax machine.

At the sending end, the machine changes the image on the document into electrical signals. At the receiving end, the signals are used to make a printer produce a replica of the original document.

Using a radio link, facsimile copies may also be sent to motor vehicles, ships and aircraft, a facility often used by the armed forces.

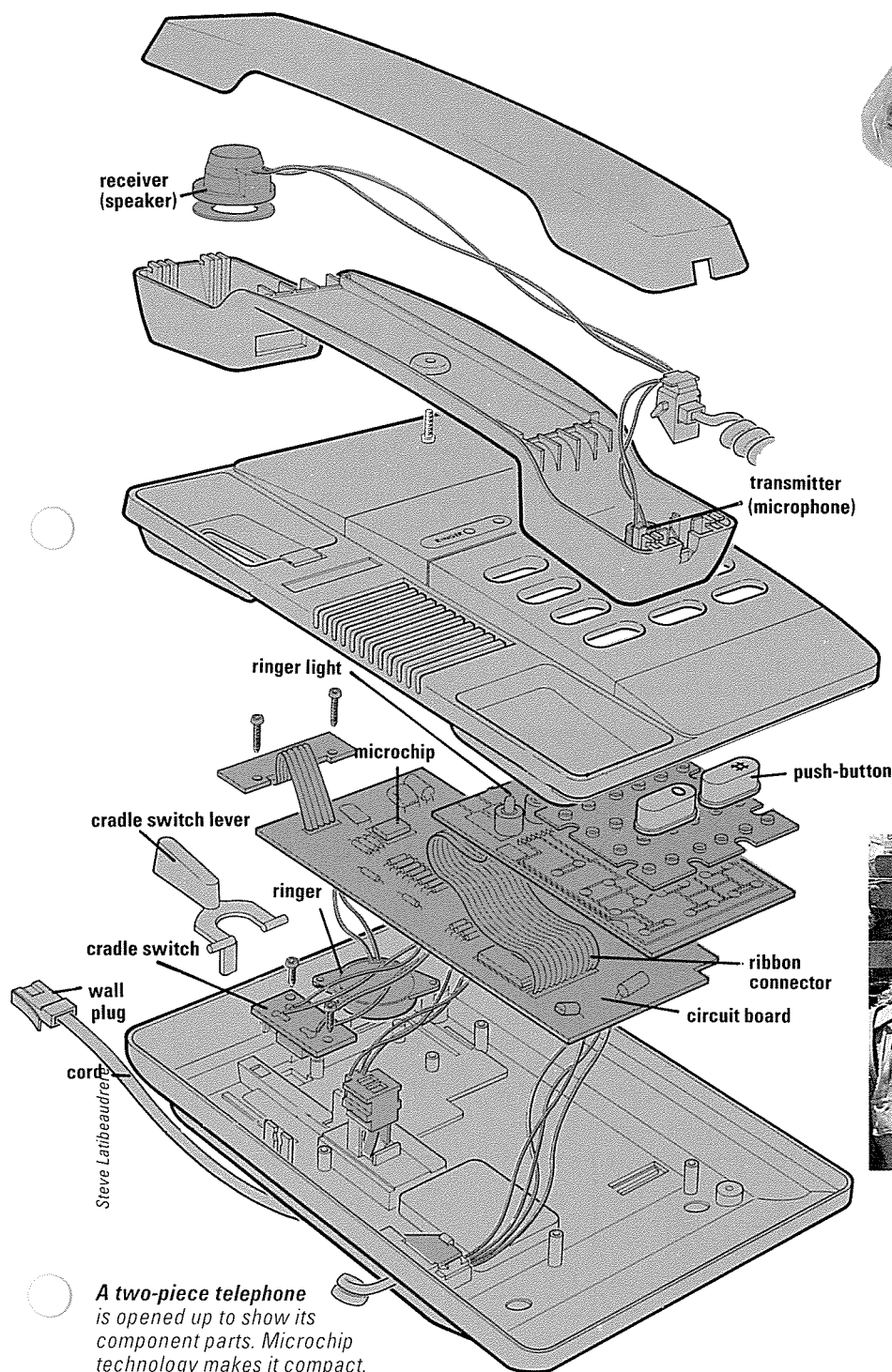


THE TELEPHONE REVOLUTION

DIGITAL SYSTEMS

CELLULAR PHONES

OPTICAL FIBRES



receiver
(speaker)

transmitter
(microphone)

ringer light

microchip

push-button

cradle switch lever

ringer

cradle switch

ribbon connector

circuit board

wall plug

cord

Steve Latibeaudre

A two-piece telephone is opened up to show its component parts. Microchip technology makes it compact, reliable and versatile.

THE WORD 'TELEPHONE' means literally 'sounds from afar'. But today's telephone system can do much more than just carry our voices around the world. Computer data, pages of text, and even handwritten notes or complex artwork can all be sent down modern telephone lines in a matter of seconds.

New types of phone are now available with electronic memories that can store frequently used numbers, automatically re-dial an engaged line, or even transfer incoming calls to another number when a person is away.

Cordless phones that use radio waves instead of cables are also becoming popular, and people with mobile phones fitted in their cars can make calls to any part of the



John Watney

The radio telephone, once used mainly by military and emergency services, is now used by millions in a new form – the cordless telephone. In both types of equipment, messages are sent and received by radio to give mobility.

world by means of radio networks, just as if they were sitting at home or in their office. Most remarkable of all, in some areas, phones are being linked not by ordinary cable, or even by radio waves, but by slender strands of glass along which messages travel by laser light.

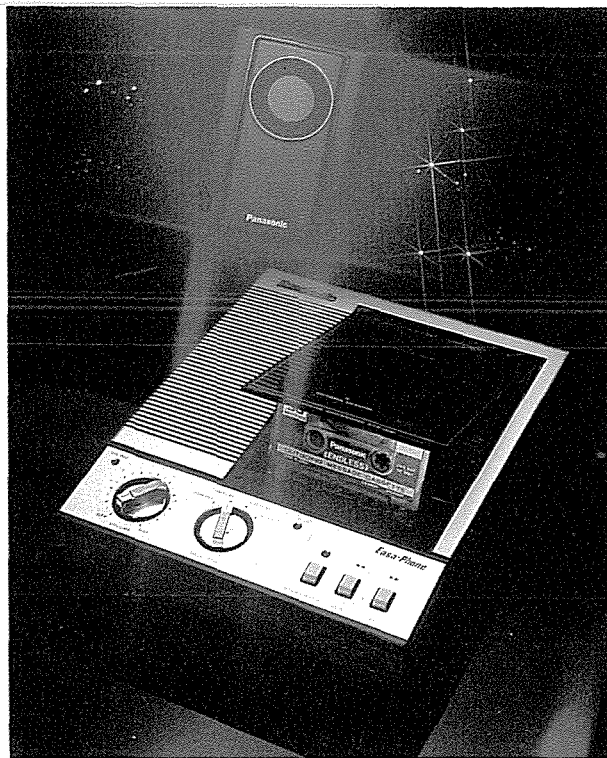
When you talk on the phone, your vocal chords set up sound waves in





A translation system developed by British Telecom. The computer displays what it thinks the speaker has said. When the speaker gives confirmation, the translation is sent.

An answering machine records callers' messages when the owner is elsewhere. He can hear calls by dialling his number and holding a remote control bleeper (top) to the mouthpiece. This has a pre-set tone that activates the tape to rewind and play.



the air. As these sound waves enter the mouthpiece of your phone, they are transformed by a small microphone into electrical waves of a matching shape. The waves of electricity then speed along cables in the phone network and through exchanges, which direct them to the earpiece of the receiving phone. There a miniature loudspeaker converts the electrical waves back again into the sound of your voice.

Digital system

In years to come, phones will work in a different way. The present system is called analogue transmission because the electrical waves are analogous, or similar, to the

spoken sound waves. But an increasingly important task of the phone network is to carry data between computers and other electronic machines. Computers operate using digital signals rather than analogue, so that communication between computers would be greatly improved if the phone system itself were to be made digital.

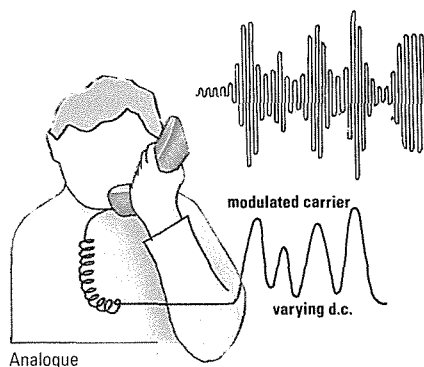
In a digital phone, your voice would first be changed into an electrical wave as before. But then the height of this wave would be sampled thousands of times a second to yield a series of numbers. Finally, these numbers would be turned into a stream of electric pulses — on/off binary digits, or

'bits' — which would then travel through the telephone network. Digital circuits are generally more reliable than analogue circuits and the effects of interference and circuit noise are more easy to eliminate from digital signals.

Already, many exchanges have been fully computerized and even long-distance trunk lines are on the digital system.

Modern exchanges equipped with powerful micro-electronic circuitry, can provide a wealth of new services, too, including voice synthesis. From an electronically stored library of responses, a caller can be given directory assistance, information on cost of calls, or any other

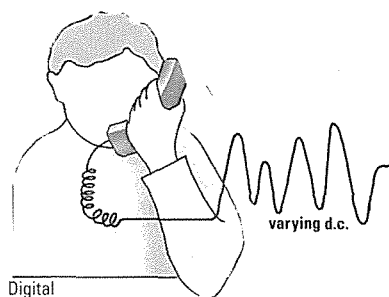
ANALOGUE vs DIGITAL SIGNALS



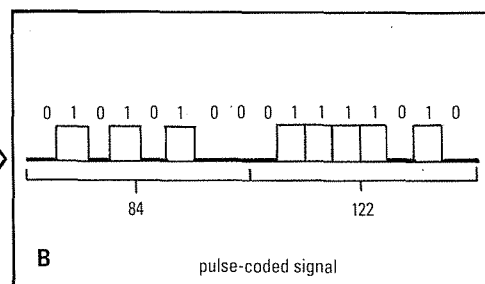
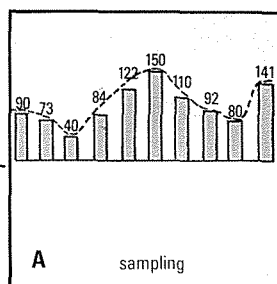
Analogue

Most telephones still use analogue signals. The signal from the telephone to the exchange consists of a varying direct current (d.c.). At the exchange, the sound signal can be used to modulate (vary) a high-frequency alternating current (a.c.) 'carrier' signal. This is economical since many carriers can be sent along the same cable. In the newer digital systems, the current from

the phone is 'sampled' 8,000 times per second (A). Each time its strength is measured as a number ranging from 0 to 255. These numbers are sent along the line in 'binary' form, using only the digits 0 to 1 (B). Each 1 is represented by a pulse, each 0 by a space. At the other end, the information is reconstructed as an analogue signal and turned into sound.

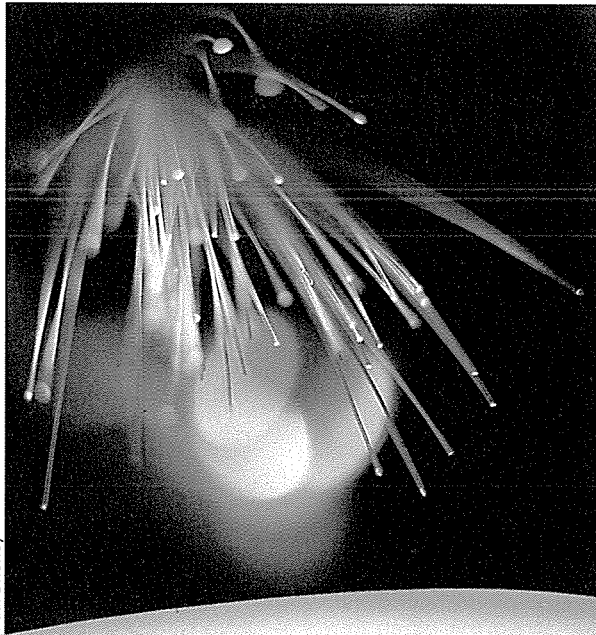


Digital



Hair-thin optical fibres can carry thousands of simultaneous phone conversations. The light waves that pass along each of these fibres can be seen glowing at the tips.

Light waves bounce off the interface between the core and the outer 'cladding' of an optical fibre. The core is typically $\frac{1}{20}$ mm across, but can be as narrow as $\frac{1}{1000}$ mm – roughly equal to the wavelength of light being used.



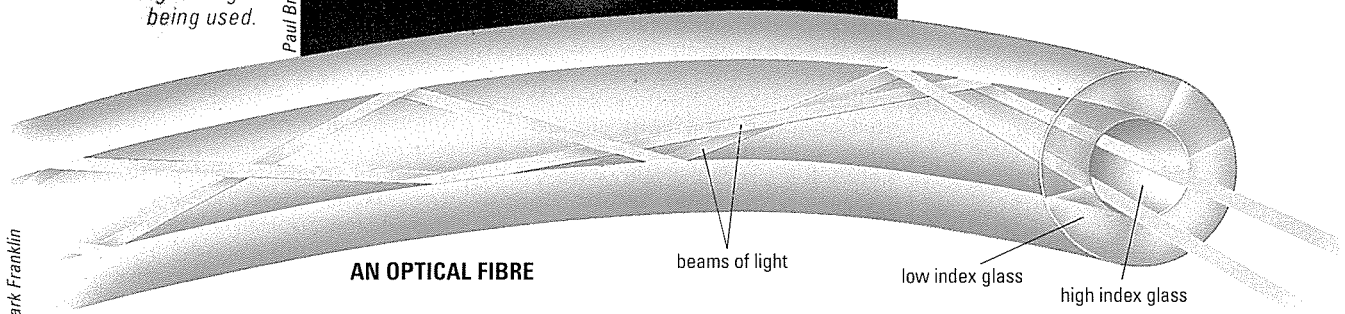
Paul Brierley

phone number, the signal enters the radio network and then travels from cell to cell, guided by computers, until it reaches the one with the receiving phone in it. A transmitting aerial linked to the cellular phone – perhaps on the roof of a car – is used to transmit a reply.

Radio phones are already available on some trains and are likely to become more and more common on all forms of public transport in the future. Soon, wherever you happen to be – on an inter-city train, a long-distance bus, or plane – you will have the facility to make a trans-Atlantic phone call to anywhere in the world.

Optically speaking

Most telephone calls today travel as electrical waves along thick copper



Mark Franklin

messages that may be helpful. In the more remote future, computers at an exchange may even be able to translate automatically the words spoken in one language to those of another.

Phones on the move

A big drawback of an ordinary phone is that it compels you to be in a certain place while you are using it. Think of how many thousands of calls must arrive every day just as someone is about to step into the bath, take a cake out of the oven, or watch a crucial moment in some

televised game of sport. Now there is a way to take calls more conveniently – the cordless phone, a phone that you can carry around the house.

This kind of short-range radio phone relies on an adaptor fixed to a conventional telephone. The electrical waves of incoming calls are transformed by the adaptor into radio waves, and then sent to the cordless phone, wherever it happens to be – in the living room, the kitchen, or even the garden. In return, words spoken into the radio phone create radio waves that, upon being picked up by the adaptor, are sent back along the phone line in the normal way.

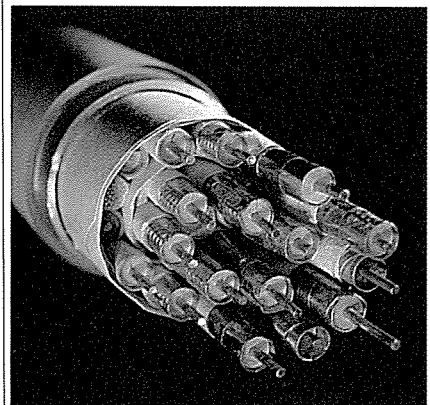
Cellular phones

Over a range of about 50 metres, such a phone works perfectly well. But it could hardly serve the needs of a businessman, for example, driving along in his car who has to stay constantly in touch with his company headquarters. Nor those of a heart surgeon who must be contacted without delay in an emergency or to perform a transplant operation. For people like these, another recent development – the cellular phone – has brought the ideal solution.

Set up around most of Britain now is an overlapping network of computer-controlled radio transmitters. Each of these covers an area around it called a cell. When a call goes out to someone with a cellular

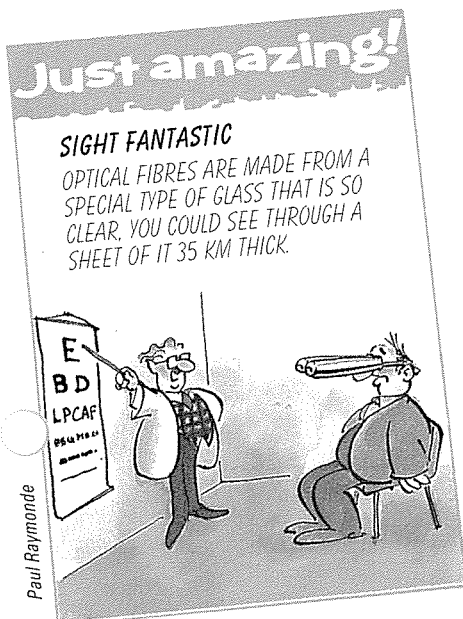
cables, either buried in the ground or strung out in the air between poles. Gradually, though, the old copper cables are being replaced by bundles of very fine glass strands called optical fibres. In these, phone messages are transmitted not as electricity, but as tiny, bright flashes of light.

A bundle of optical fibres, no thicker than your finger, can carry 10,000 phone calls at once – more than the capacity of a copper cable



Paul Brierley

Co-axial cables carry thousands of phone conversations on a high-frequency signal. Nearly 20 'co-ax' cables are bound together into a long-distance cable. Each co-ax cable consists of a central copper wire surrounded by a copper sleeve. The signal is boosted by amplifiers every few kilometres.

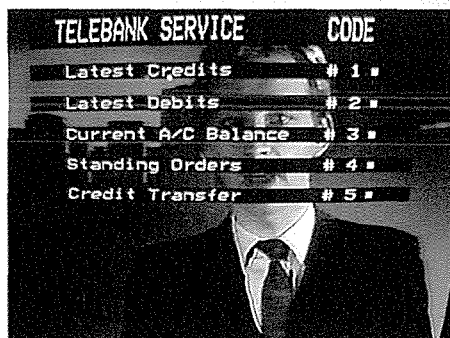


Paul Raymond



WATCHING YOUR MONEY

Telegraph Colour Library



A viewdata attachment turns your telephone and TV set into a terminal for a powerful computer. One of the many services you can get is personal banking. Here, a 'menu' of bank services is superimposed on a TV programme. If the user presses, say, 3 on his keypad, a signal is sent over the phone line to the computer. His bank balance is then flashed up on the TV screen.

The videophone has been under development by scientists since the early 1960s. But even though the technology now exists for a domestic network, the immense costs involved give it a major disadvantage.

as wide as your arm. Each of these calls, having first been converted from ordinary electrical waves, passes along the glass fibres as pulses of light generated by a laser chip or an LED (light-emitting diode). At the receiving end, the light signals are once again turned into waves of electricity.

Developed in the 1960s, optical fibres can be coiled, bent and twisted just as if they were ordinary wire. Each fibre consists of a core of very pure glass along which the light signals travel. If the light tries to escape from the sides of the tube it meets an outer cladding of a different kind of glass that bounces the light back into the core again. A phone message travelling as a beam of light suffers no interference from stray electric fields. More importantly, with data security now such a major issue, a call carried as light waves is difficult to tap.

Almost without us realizing it, the

global phone network is changing in remarkable ways. New stretches of optical fibre cable are being laid down in the United States, Britain and other countries each year. More and more calls abroad are travelling, not by undersea cable as before, but via powerful communications satellites perched high in Earth orbit. And increasingly, new electronic devices are being used to send information by telephone all across the world.

At your service

With just a small personal computer, linked by a modem to the phone, it is now a simple matter to access great libraries of information stored electronically. Known as databases, these libraries may specialize in certain technical subjects or contain general information of use to the ordinary person at home.

As well as computers, devices such as fax machines can communicate by phone. With a fax machine any sort of document or picture can be scanned electronically and its contents relayed by phone to a similar device where an exact copy of the original is printed out.

The telephone's role in alerting emergency services is well known. But now, at the first sign of trouble, people fitted with pacemakers are able to place a monitoring device over their chest, which can pick up very faint signals coming from the pacemaker and heart. Plugged into an ordinary telephone, it can then send these signals to the doctor's office or to a computer at a hospital some distance away. After the computer has compared the signals, the doctor can decide if the patient needs further treatment.

Frank Spooner Pictures

INTO THE FUTURE



▲ Portable phones may soon be in use everywhere. The user will need to be near a public 'callpoint', which picks up radio signals from the portable phone.



▲ Wherever he is, the person being called will be alerted by the radio pager built into his own portable phone, which will display the name and phone number of the caller.



▲ When he gets close to the closest callpoint, he will be able to hold a normal phone conversation with the person calling him with no outside interference.

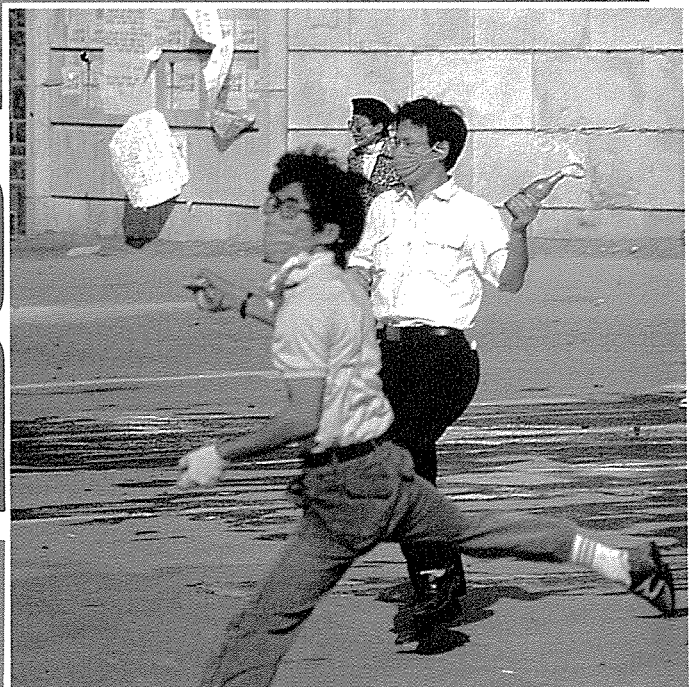
Alan Burrows





Rex Features

DANGER PATROL



A POLICEMAN WAS HACKED to death during a riot at Broadwater Farm Estate in Tottenham, London, on 7 October 1985. After a night of violence, 81 people had been rushed to hospital – 58 were police officers.

During violent riots, the police face a daunting array of weapons – iron bars, chunks of paving stone, bottles, petrol bombs and even shotguns. The need to provide the police with better protection than a helmet and a truncheon has led to the introduction of a variety of new riot control equipment.

Gas is a popular means of crowd control in many European countries. CS gas is faster acting and stronger in its impact than conventional tear gas (CN gas). Normally non-lethal, CS makes its victims feel as if they have been attacked with pepper. Exposure to thick clouds of the gas leads to coughing, vomiting and skin irritation, making any rioter incapable of causing further trouble.

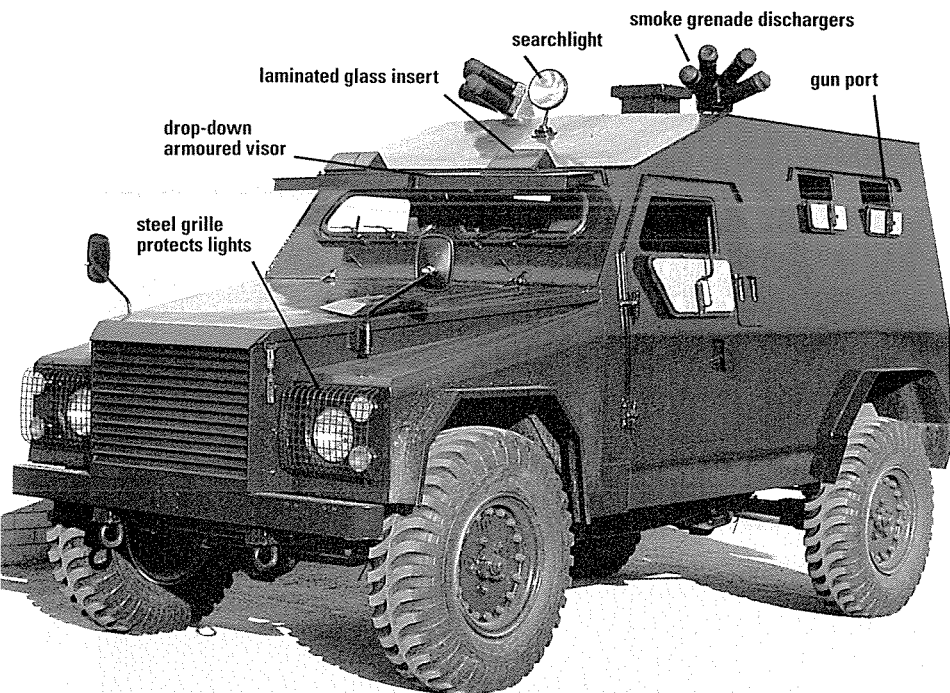
Like other riot weapons, however, CS gas has its drawbacks: wind direction can blow it badly off course, and people suffering from respiratory problems could choke to death. Also, many rioters have real-

Violent demonstrations and riots were a disturbing feature of the 1980s. British police sheltered behind shields during the 1981 Brixton riots (top). In South Korea, rebellious students hurled stones and petrol bombs at the authorities (above).

ized that the gas can be overcome by holding a cloth soaked in vinegar and water over the face.

The water cannon is an armoured truck carrying hoses that send out jets of water under high pressure. The water can be mixed with vegetable dye, which turns the riot-





The Shorland S.55 armoured personnel vehicle carries an eight-man crew. It is designed for the rapid deployment of security forces in high-risk areas, and has ports for anti-riot and sub-machine guns. Guttering below the windscreen diverts burning fuel from petrol bombs straight to the ground.

wear padded body armour made from kevlar, a tough lightweight material, originally developed for tyres. Kevlar will withstand all but a bullet from a high velocity rifle.

Protective clothing

The British riot police — the 900 strong Territorial Support Group (TSG) — wear fire resistant clothing as protection against petrol bombs. The material — Nomex — combines much of the strength of Kevlar, with a far higher melting point. The TSG's only weapon is a long truncheon — almost a metre in length.

Makrolon polycarbonate is one of

Short Brothers PLC

ers green or blue, making the follow up and arrest of the trouble-makers easier. Water cannons, however, have one major disadvantage — they can run out of water before the riot ends, leaving the vehicle open to hijacking.

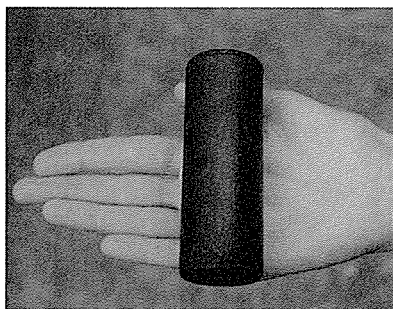
Armoured vehicles

In the CIS, police use tanks to intimidate rioters, but control can be more effective if the police keep a low profile. The Shorland armoured vehicles have become a successful export from the UK. Based on the Land Rover, they have a makrolon polycarbonate skin and steel grilles fixed to the windows. Shorlands are easier to drive and control in narrow city streets than tracked vehicles.

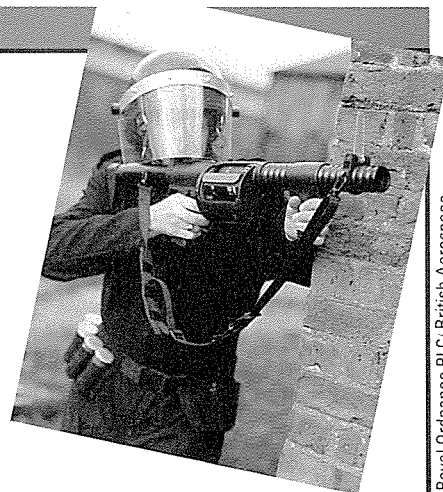
In the UK, the police try to quell

THE BATON ROUND

The rubber bullet, or baton round, was introduced in Northern Ireland in 1970 by the British Army. The bullet is 37 mm in diameter and weighs 142 g. Baton rounds are fired from weapons such as the Smith and Wesson Grenade Launcher, or the Arwen 37 multi-purpose gun (right). Fired low to hit the legs and torso, the bullet is intended to cause pain without severe injury. The main



Pacemaker Press International



Royal Ordnance PLC British Aerospace

problem with the rubber bullet is that it tends to be inaccurate and, if fired at short range, it can be fatal. More recently, the plastic bullet has replaced the rubber one but, while it is more accurate, it is still potentially lethal.

Just amazing!

MORNIN' ALL

WHEN 4,000 HIPPIES DESCENDED ON STONEHENGE TO CELEBRATE THE 1988 SUMMER SOLSTICE, THEY WERE MET BY MORE THAN 1,000 POLICEMEN FROM 17 FORCES — THAT'S ONE POLICEMAN FOR EVERY FOUR HIPPIES!



Paul Raymond

riots without using firearms, and there are a number of riot tactics presently in use. During the 1981 riots in Toxteth, Liverpool, the police favoured 'hot pursuit' tactics, which involved police vehicles being driven at speed towards rioters to disperse them. In one unfortunate incident, the police van mounted the pavement, killing a local resident.

To enable police to arrest the most violent of the demonstrators, 'snatch squads' are brought into action. A small number of specially selected officers rush out from behind the cover of heavily protected riot police and grab the chief troublemakers.

Lightly armed, the squad normally

the most important materials used for protecting the police. This clear, tough plastic was first developed for astronaut visors. When fitted as a protective helmet, it can withstand rocks thrown at short range and, although it may crack during a heavy assault, it does not shatter.

After plastic visors, two types of shield were introduced. The small shield is useful for mobile groups, while the one and a half metre shield gives full body protection.

Police at risk

The future of riot control is uncertain. Tests on disabling weapons such as electronic stun and laser guns and fast acting tranquillizer darts have proved inconclusive so



far. If the police resist using violence to conquer violence, then they continue to put themselves at risk when faced with a rioting crowd.

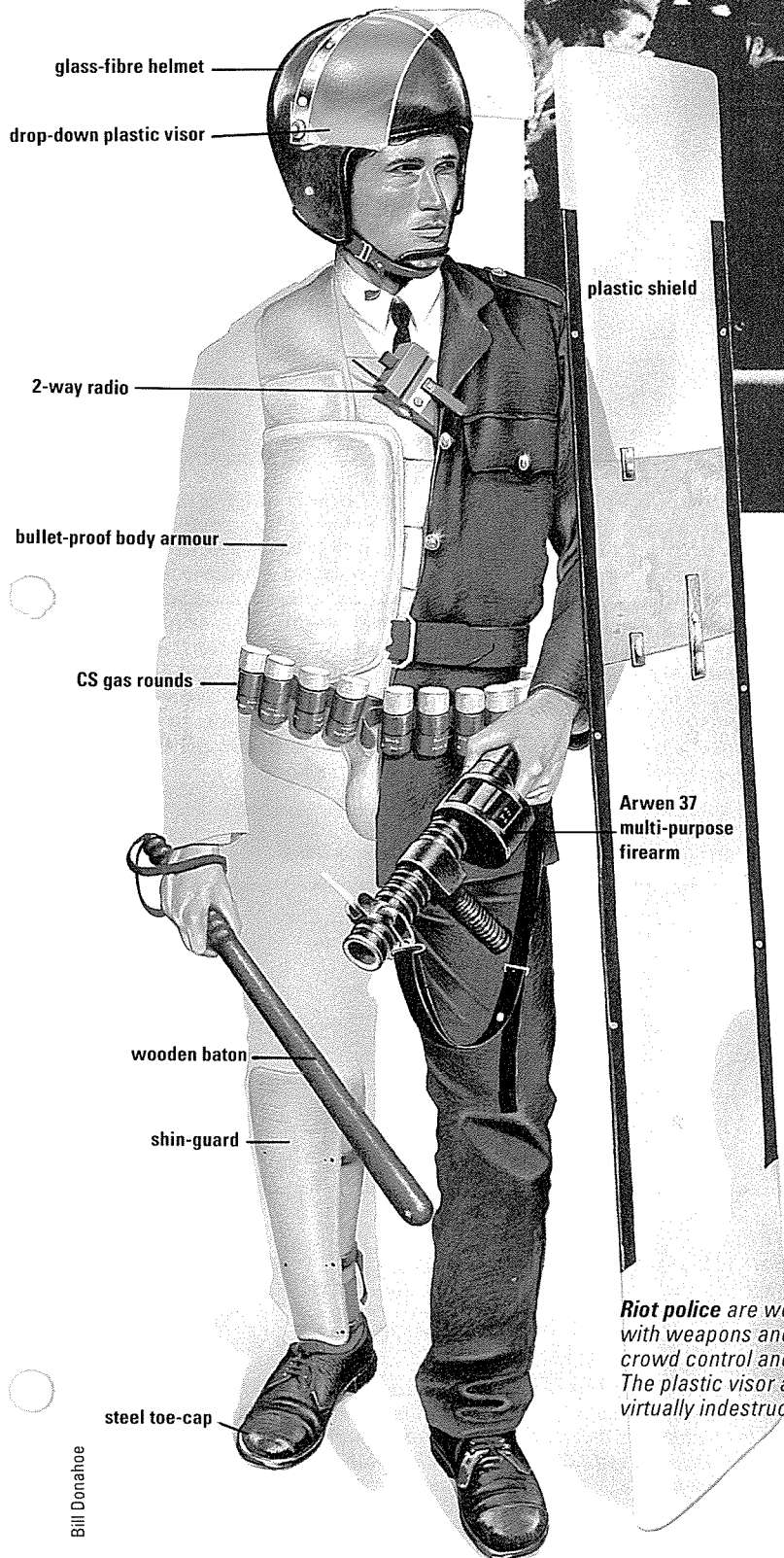
The nerve of those police earmarked to combat riots, however, is matched only by the courage of the men in the bomb disposal unit.

Bomb disposal

The battle between terrorist and bomb disposal expert is harsh. It is not unusual for a bomb to be

LOOKING FOR TROUBLE

In the wake of the ever-rising tide of football hooliganism, the police have turned to new technology to stamp out violence. Vans fitted with roof-mounted platforms provide police observers with a good view of the spectators. Closed-circuit TV cameras show general views of the crowd and can zoom in to give close-up shots of individuals when a disturbance occurs.



Riot police are well equipped with weapons and armour for crowd control and close combat. The plastic visor and shield are virtually indestructible.



Popperfoto

Mike Goldwater/Network

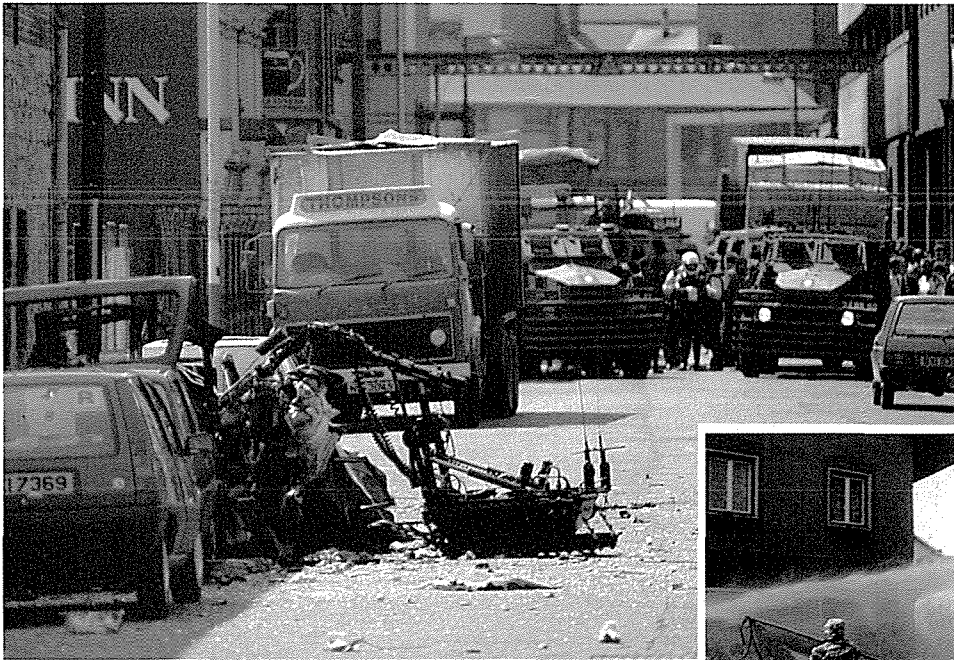
planted as bait, and the surrounding area mined and perhaps covered by snipers, with the intention of putting the 'explosive ordnance disposal team' (EOD) out of action. The bomb may be fitted with devices to prevent it being moved or handled. It may also have sensitive electrical contact switches that react to vibration, and cause the bomb to explode if it is moved.

Anti-lift, anti-open and anti-disturbance switches became so common that a remote controlled bomb disposal robot was created to investigate suspected terrorist bombs.

The Wheelbarrow

'Wheelbarrow' is the name of a small remotely controlled tracked vehicle, which can be adapted to carry a number of devices. It has an articulated arm carrying a closed circuit television camera and a floodlight. This allows the Wheelbarrow to drive up to the bomb, and send a picture of the device back to the EOD team. It can also lift the





An army robot, known as the Wheelbarrow, investigates a bombed car in Belfast. Besides sending TV pictures of the wreckage to the bomb disposal team, the Wheelbarrow can also take x-ray equipment to the scene and return the exposed film. If another bomb is found, the machine can disarm it or move it to a safe place to be exploded.

bomb and turn it around if a closer inspection is necessary. Should the bomb explode, only the machine is damaged.

The Wheelbarrow can also fire a disrupter at the bomb. Either a special shotgun charge, or a shot of water discharged at high speed, rips into the bomb and severs electrical connections so quickly that it has no time to function.

An improved version of Wheelbarrow known as 'Marauder', was also developed by the British Army. Marauder has longer tracks and, unlike Wheelbarrow, can even climb up stairs.

Some bombs, cannot be dealt

The powerful jet from a water cannon is an extremely effective means of breaking up groups of unruly demonstrators.



G. Sommer/Gamma/Frank Spooner Pictures

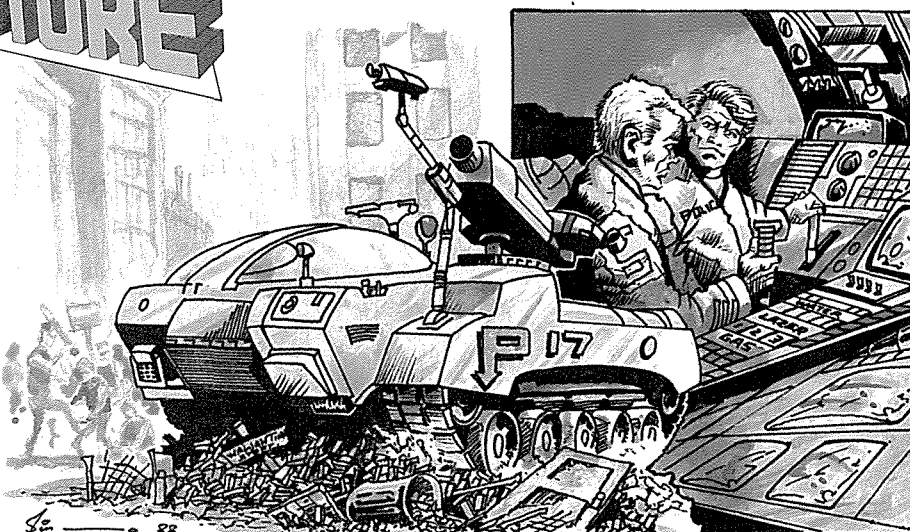
with by remote control and have to be dismantled physically. Usually the first step in examining a bomb is to X-ray it. This reveals the internal mechanism. If the bomb is a simple device, the EOD team can slice open the outer container and cut the wires leading to the bomb detonator – the key component. Often the designer of the bomb will have incorporated some kind of booby trap to prevent it being tampered

with. If the bomb uses a battery to power the detonator, then freezing the bomb will render it inert and safe to be dismantled. Alternatively, a hole may be drilled in the bomb casing and electrically conducting foam pumped in. This shorts out the circuits and prevents detonation.

The bomb disposal expert can never relax. Each bomb presents problems as the terrorist tries to stay one jump ahead.

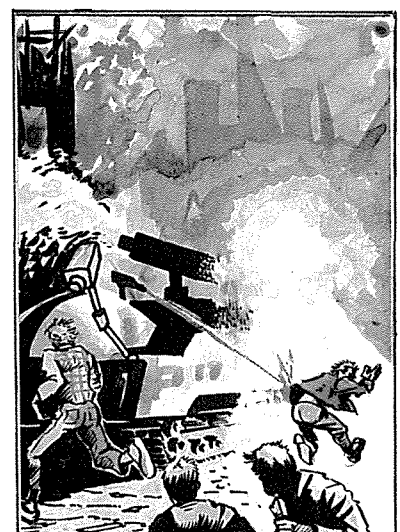
INTO THE FUTURE

AUTOMATIC RIOT CONTROL



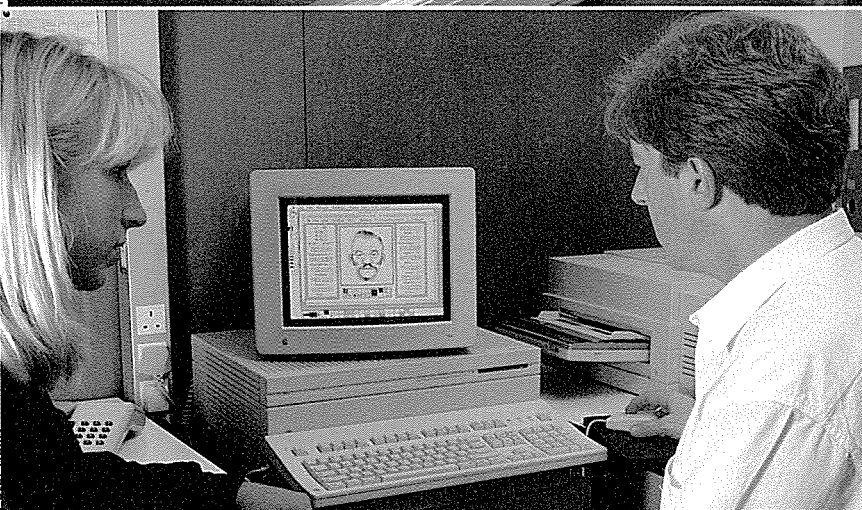
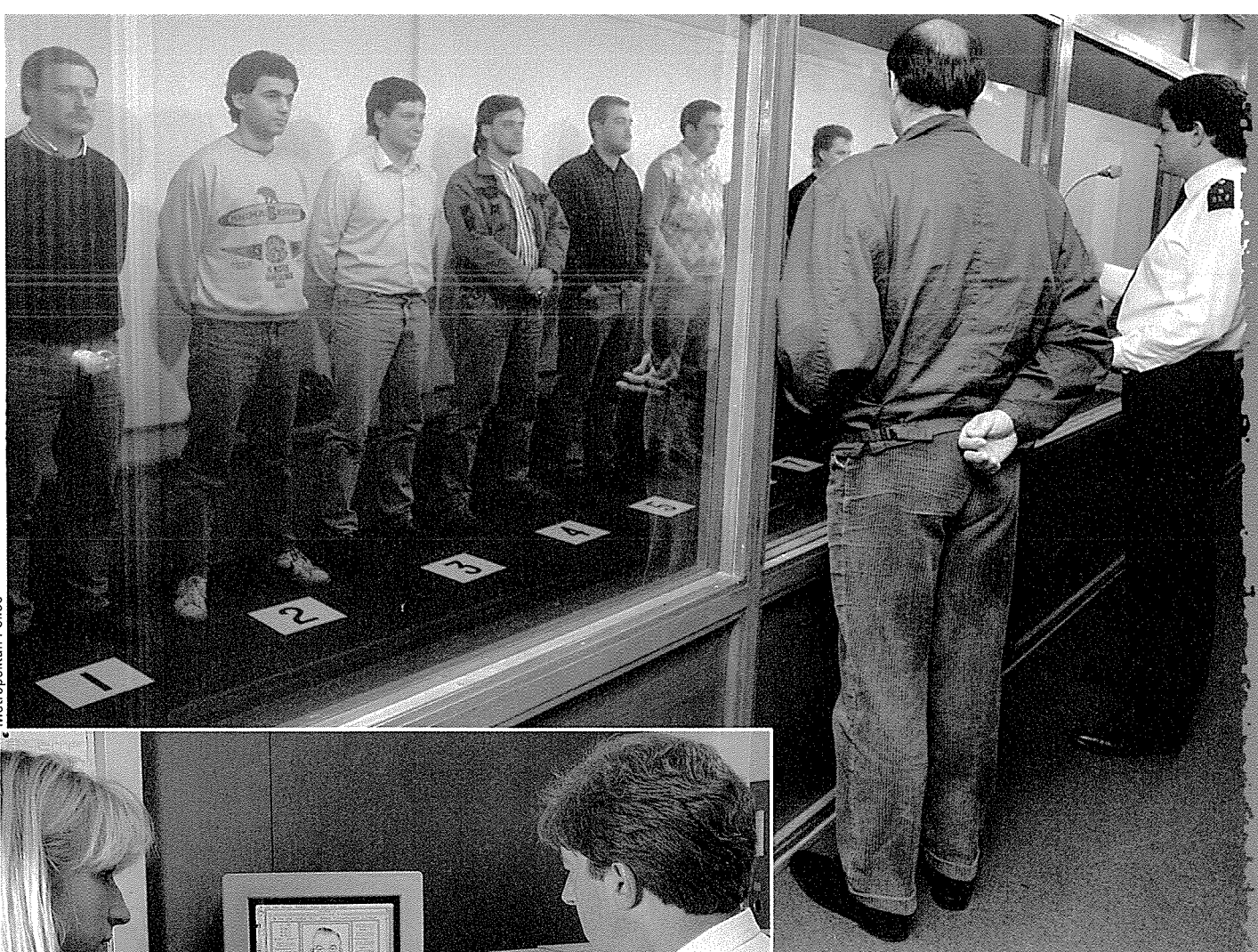
▲ Not much would stop a riot control vehicle of the future. It could be equipped with loudhailers, water cannon, knockout gas, stun guns and laser weapons.

▲ Inside the vehicle, operators could watch and record the pictures as they direct, focus and zoom the infra-red TV cameras mounted on the vehicle.



▲ One blast from a stun gun could temporarily paralyze a violent rioter, so that he could be taken into custody without violent resistance.

Alan Burrows



Picking out faces at an identification parade, safe behind a two-way mirror. The Mac-a-Mug system (inset), which can be used by a civilian as easily as by a trained police officer, is already in operation in Canada and the USA. A similar system could replace Photofit.

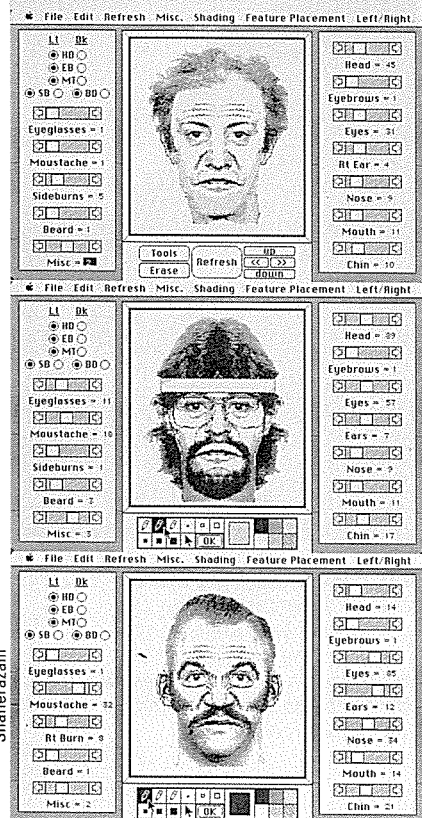
IDENTIFYING THE CRIMINAL

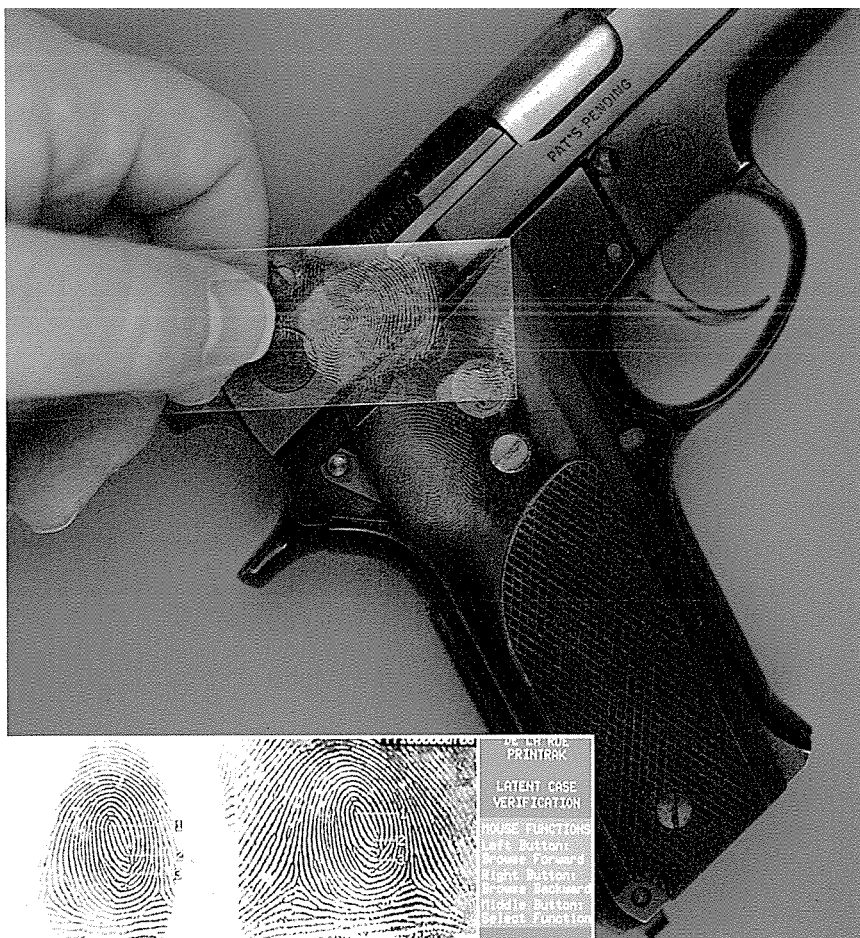
-  PHOTOFITS
-  FORENSICS
-  FINGERPRINTS

YOU ARE WALKING ALONG the High Street, when two men suddenly burst out of the Post Office, each of them holding a bag and brandishing sawn-off shotguns.

You hide in a shop doorway, but as the men run down the street, one turns his head and looks straight at you. For that split-second, you see his face clearly. Through no choice of your own, you have just become an eye-witness to an armed robbery.

Any witness to a robbery will probably be questioned by the police, asked to provide a statement, and will then be asked to try and describe the robber he or she saw. Most British police forces use a





PRINTRAK
LATENT CASE VERIFICATION

HOUSE FUNCTIONS
Left Button: Browse Forward
Right Button: Browse Backward
Middle Button: Select Function

Browse On

Case Selection
Next Case
LACE L | LACE R
Non-Ident.
Zoom Color
Ident.
Graphics Off
Camera

De La Rue

Rank	File ID	Classification	F4
1	77100000700	WWWWUUUUUU	2870
2	77200000700	WWWWUUUUUU	704
3	33300001600	WWWWUUUUUU	700
4	11022000800	WWWWUUUUUU	502
5	14100789100	WWWWUUUUUU	358
6	110220015010	WWWWUUUUUU	352
7	332000008911	WWWWUUUUUU	342

LATENT CASE VERIFICATION Stn: 1 Oper: DOUG #Resp:100 +

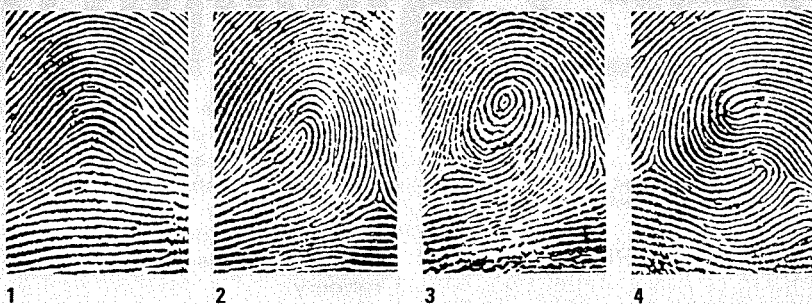
A fingerprint is 'lifted' on to a slide for comparison. The Printrak system (inset) can match scene-of-crime prints with those on file in minutes. One burglar in the USA was identified by Printrak two hours after the crime was committed.

system called the Photographic Facial Identification Technique, or Photofit. The male Photofit set alone contains over 550 examples of hairstyles, eyes, noses, mouths and chins. By putting these features together in different combinations, it is possible to construct over 100 million different faces.

However, most witnesses only catch a fleeting glimpse of a face,

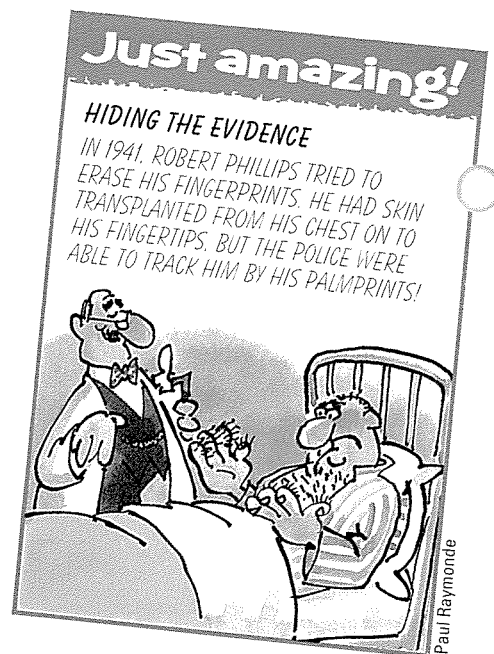
often from a distance, and sometimes at night. Trying to remember one face from the hundreds we see every day, and keeping the image fresh in our minds is no easy task. Also fitting together the different Photofit cards can sometimes be confusing. To remedy this, a number of systems have been invented on computer, which are very much more versatile.

FINGERPRINT TYPES



There are four main types of fingerprint. 1 Arches, which make up about 5% of all prints, 2 loops, accounting for about 65%, and 3 whorls and 4 com-

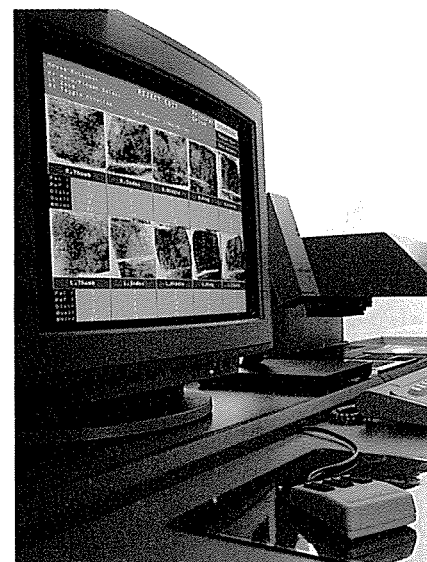
posites, about 15% each. Arches are further sub-divided into plain and tented arches. Loops are also sub-divided into radial and ulnar loops.



Although they work on the same principle as Photofit, the computer systems are able to merge the different features together to form a full face. One disadvantage of Photofit is that the finished face looks something like a jigsaw, and is only in black-and-white.

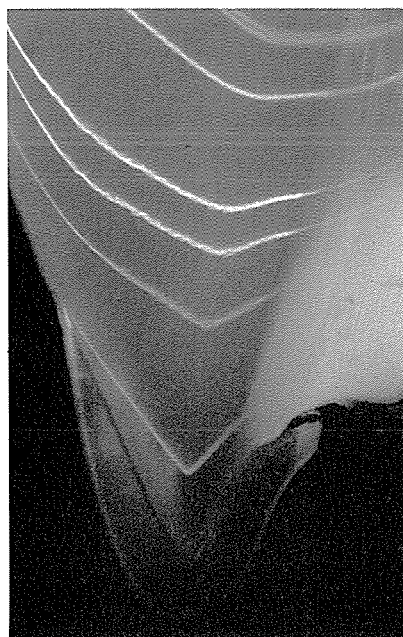
Faces on disk

One of the first of the new generation of computer systems is called Videofit, and is used by the BBC's *Crimewatch UK* programme. The system is very expensive but it is highly versatile. It uses colour, can produce a multitude of different flesh tones, and can add stubble or acne, or even a wig – and make it look real or false, just as the wit-



The Printrak matching system checks fingerprints on file. One person may have prints of more than one type: the suspect's prints shown has composites on his left thumb, and whorls on his left index finger.





ness remembers. If the witness saw the face under street-lighting, Video-fit can even simulate this, casting shadows across the face to highlight a long nose or sunken eyes.

A smaller-scale version of Videofit, designed to run on an Apple Macintosh computer, is called Mac-a-Mug. It is cheaper, and is even more versatile. The program itself is 1200K long, and consequently can store a great deal of information. It has 185 head shapes, 118 eyes and eyebrows, 66 noses, 46 chins and even 37 different types of moustache. With all the combinations, it is even possible to alter one side of the face only, to make one ear higher than the other. Mac-a-Mug or a similar system is likely to overtake the old method of albums of 'mug-shots' in local police stations, which don't have access to large and expensive computers.

Tooth enamel is the hardest substance found in the human body. Consequently, the teeth survive longer after death than flesh and bone. All dentists keep detailed records of their patients' teeth: the shape, position and condition are all catalogued. When evidence is required in order to establish the identity of a murder victim, the police first compare the dental pattern of the corpse with records of missing persons in their computer system.

Also a chemical called tetracycline can be added to the victim's teeth, which highlights the growth lines. In the same way as the rings inside a tree-trunk indicate its age, these fluorescent lines show how old the tooth – and therefore the victim – was.

Aside from consulting witnesses, police also test the scene of the crime for fingerprints, and other clues. Although the unique nature of every person's fingerprints has been understood for centuries, they only began to be used in the detection of criminals at the beginning of the century. Today, the National Collection located at Hendon contains over two and a half million sets of fingerprints.



Identifying the 'dabs'

Fingerprints left by a dirty hand or in blood are easily visible, but a second group, called latent, or hidden, prints; are invisible. Latent prints are the impressions left by sweat-moistened ridges of the hand on polished surfaces such as glass or metal. Their existence is usually detected by shining an oblique light

A lie detector monitors the heart rate, breathing and perspiration. It detects any disturbance to normal body rhythms, caused by the extra adrenalin produced when a lie is told.



Lafayette Instrument Co.

IDENTIFYING THE CRIMINAL

on the surface and then dusting the area lightly with a brush dipped in aluminium powder. The prints can then be photographed and 'lifted' from the surface using a special transparent tape which can then be stuck on card for use as evidence in court.

Finding the print is only the first step. Now the police must try to find out to whom the prints belong. They are rarely lucky enough to find a complete set of 'dabs' at the crime scene but must work on the blurred impression of a single finger.

In these cases, a highly skilled technique known as poroscopy may be employed. This involves comparing the pattern of the individual sweat pores which, like the

CLASSIFYING BLOOD



Spillage of blood is a common occurrence in violent crime, and the examination of bloodstains can give a great deal of information about the way in which the blood was spilt, and about the person who shed it.

Blood that is allowed to drip freely on to the ground leaves a highly characteristic pattern of drops and splashes, which is quite different from the pattern left by blood that has spurted from a wound. And because it is difficult to remove bloodstains at the scene of a crime, even the smallest trace that had dried into a corner would be enough to analyse for blood group. As well as analysis of the pattern of dripping blood, there is also a complex system used for the classification of different types of blood.

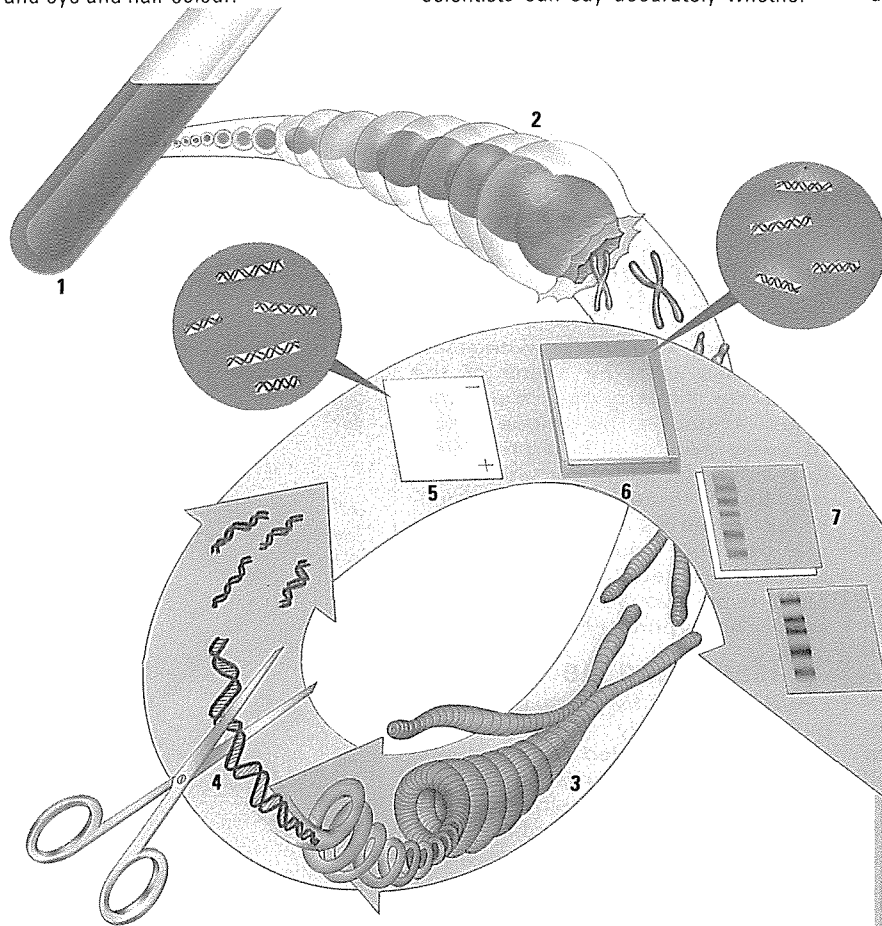
Under the ABO grouping system, there are four main blood groups. Each red blood cell has a thin shell which contains chemicals called antigens. Any red cell which has A antigens is in group A, any cells with B antigens are in group B. Those cells with both types of antigens are in group AB, and those with neither of them are classified as group O. In the UK 47 per cent of the population are in group O, 42 per cent are group A, 8 percent group B, and just 3 per cent group AB.



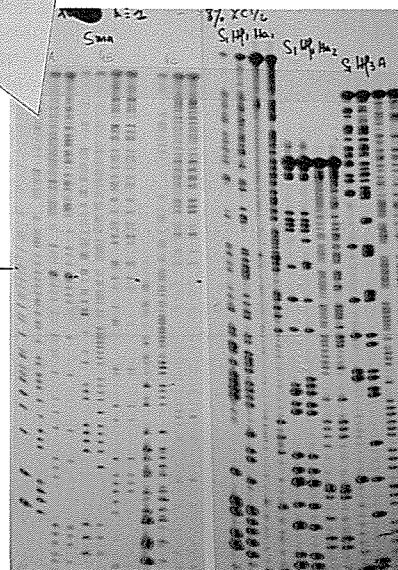
DNA (deoxyribonucleic acid) is a string of chemicals that is present in every single cell of the body. It contains all the information necessary to make a human being: as well as the correct numbers of arms and legs, it also contains such details as personality and eye and hair colour.

A large part of the DNA is the same for every human: two arms, one head, and so on. But it is the detail of hair colour, blood group and personality that is unique to each person. By comparing a suspect's DNA pattern with that of a sample found at the scene of the crime, scientists can say accurately whether

the suspect committed the crime or not. Although many people share one or two DNA characteristics, only two people in every ten billion have identical DNA patterns. Since the entire world population is only five billion, it is safe to say that each person's DNA 'fingerprint' is unique.



Genetic fingerprinting A blood sample is taken (1), and the DNA is extracted (2). Each strand of DNA is isolated (3), and chemically sliced into fragments (4). The DNA is transferred to a nylon sheet (5), and the parts of DNA that are unique to each person are made radioactive (6). The radioactivity shows up (7), and is developed on to an x-ray plate (8). The different plates for the suspect, the victim, and the evidence at the scene of the crime are compared. Since the DNA is present in every cell in the body, DNA taken from blood can be matched with DNA taken from skin, saliva, or any other body material without the chance of a mistake or mismatch being made.



Philippe Plailly/SPL

ridge patterns themselves, are unique to the individual.

But whatever the method, the standards of proof remain the same – 16 points of similarity must be established between the prints found at the crime scene and those stored in the crime file to be sure of identification.

The way forward

All prints are now stored on microfilm, together with a series of code letters which uniquely describes each individual pattern. The 'Videofile' computer system is fed information on the print found at the crime scene and the Automatic Fingerprint Recognition system (AFR) then sifts out those prints which best fit the description. The operator can then compare the impressions on a special split-screen VDU to confirm the match.

However, even more accurate ways to identify criminals are now being developed. Instead of using fingerprints, which have quite a

GENETIC TEST CASE

On 13 November 1987, Robert Melias was convicted in Bristol Crown Court of rape. He was the first person in the world to be imprisoned by genetic fingerprinting.



South West News

high error possibility, scientists can now use the body's own microscopic building blocks – unique to each person – to pin down a suspect's identity. The process, called 'gene-

tic fingerprinting', uses the unique design of DNA.

With genetic fingerprinting, then, a murderer could leave no fingerprints, no marks, or anything at the scene of the crime apart from an eyelash or some saliva – and this would still be sufficient to analyze and prove him guilty of the murder.

This type of fingerprinting has proved particularly successful as evidence in rape cases. Indeed, during 1988 eight convictions for rape or murder were secured in Britain and seven in the USA, based on DNA fingerprint system.

BUILDINGS FOR THE FUTURE

HOW WILL HUMANS BE living 30 years from now? Ten kilometres up in soaring skyscraper-cities? In caverns buried deep in the ground? Or in a series of huge globes, each holding millions of people?

One thing seems certain, the buildings and communities in which people spend much of their lives will be very different in years to come from the way they are today.

Buildings in the next century will have to be much more energy-efficient. Our current supplies of fuels are gradually running out, and with such a massive increase in

Rex Features

Lloyd's of London. This magnificent structure of glass and aluminium houses 6,000 workers. The 14 floors, built around a central atrium, provide a temperature-controlled, well-lit environment for the building's inhabitants.





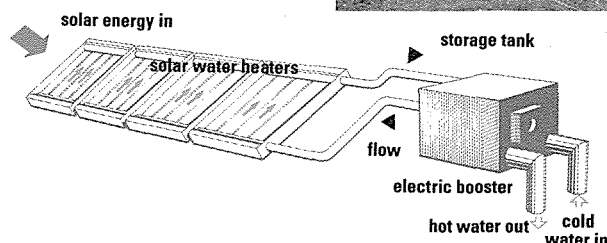
A thick brown smog settles over the city. This kind of smog can cause chronic bronchitis, irritation of the eye, and severe breathing problems. As well as affecting humans, gases from industrial plants lead to long-term environmental damage.

Rex Features



SUN ENERGY

A solar water heater uses no electricity – the water is heated only by the rays of the sun. Cold water enters from the main system and is piped to the solar panels.



population a great strain is being placed on the planet.

Another important factor is that, in almost every country, more and more people are moving into towns and cities. In trying to solve crucial urban problems such as crime, pollution, overcrowding, and traffic congestion, the appearance of our cities is likely to be transformed.

Future cities, although large, may include wide areas of parkland and woodland, extensive car-free zones for pedestrians and cyclists, and housing that is pleasant both to look at and to live in.

At the opposite extreme is the fear that many of the world's cities may be overwhelmed by problems such as pollution and fast-rising populations.

Yet such are the difficulties facing cities today that some architects

and planners are suggesting a number of radical alternatives to the standard type of living accommodation.

Houses built today are generally well insulated and reasonably cheap to run. But they still depend heavily on electricity and gas made from fossil fuels – coal, oil and natural gas. Not only do these fuels, used in large quantities, irreparably damage the earth's atmosphere, but they are also set to run out in the next century. This will force scientists to come up with new designs for our homes and new ways of obtaining energy. But not all are futuristic dreams – some are already happening.

Living underground

Underground or 'earth-sheltered' houses are already popular in the United States and other countries. These take advantage of the natural insulating properties of soil. Three metres below the surface, the temperature stays between 10 and 20 degrees Celsius regardless of the weather above. Since very little heat can pass through its walls, an underground home is easy to keep warm in winter and remains cool even on the hottest summer day.

An underground house nestles into a hillside. In the foreground of the picture is a solar panel. Underground homes can be any size without becoming eyesores, and they are naturally insulated by the soil. Homes like this – although unusual – are increasingly popular in the United States.

Because the panels are made of special glass, they can get very hot indeed. While the water flows through panels, it is heated by the direct rays of the sun. When it returns to the storage tank, it is kept hot by a small electric booster unit until it is needed. These units are around 55 per cent efficient – that is, they lose a little under half the energy available.

Underground houses have the extra advantage of blending in well with the environment. Often, very little of the house is visible from outside and many such homes could be built in an area without creating a 'concrete jungle'.

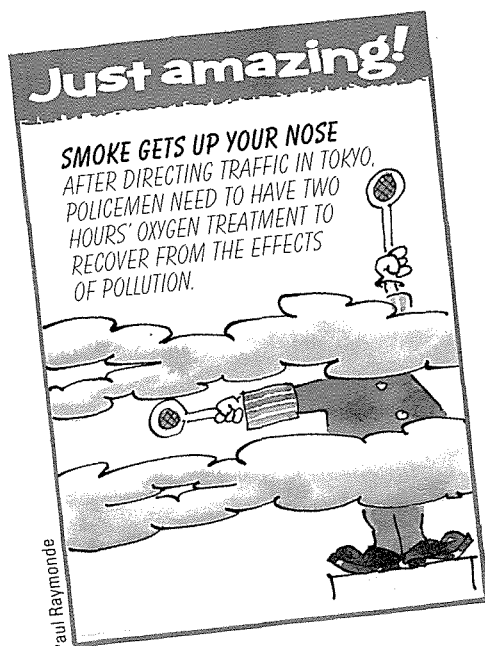
Visions of the future

Architect Paolo Soleri has spent years in the Arizona desert turning his ideas for a city, called Arcosanti, into reality. Since 1970, thousands of students and other volunteers have come to the desert to work on Soleri's project – to build a city within a single building.

Soleri calls his proposed com-



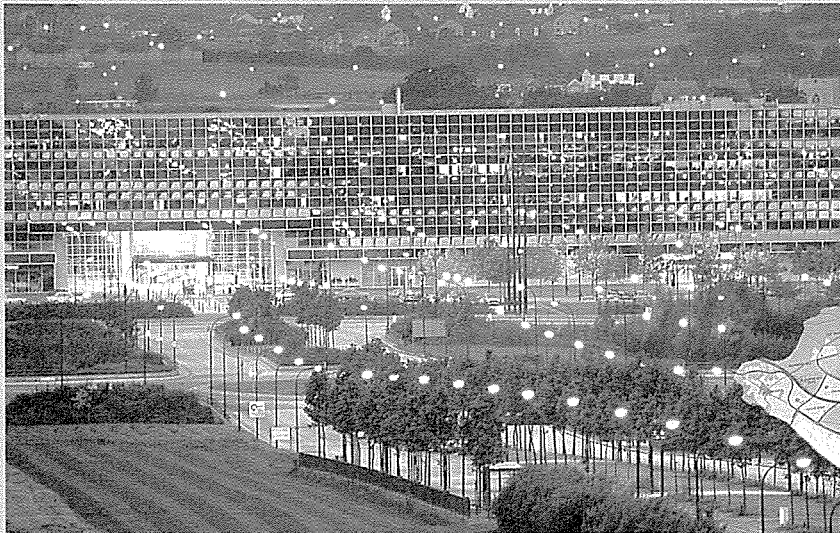
ES10



Paul Raymond



THE BEGINNING OF A NEW TOWN



A new town, such as Milton Keynes in the UK (left and below), rarely starts from scratch, but is likely to be built on the site of a village. The initial considerations in each case tend to be different – in some instances, the drainage system might be a first priority and in others, a new road system.



The Creative Company Milton Keynes

munity an 'arcology', that is, a blend of architecture and ecology. His goal is to create a place where thousands of people can live and work without the usual stresses of urban life. So far, only a fraction of the project is complete, but by attracting visitors to the site, has shared with others his vision.



Dome city

A very different futuristic scheme is the brain-child of famous American architect Buckminster Fuller. Take a city, suggested Fuller, and totally

enclose it within a transparent 'geodesic' dome – a dome made of interlocking shapes like triangles. No beams would be needed to support it, so the dome could be almost any size. Protected by their clear bubble of special plastic, the city's inhabitants would never have to suffer from bad weather. On hot summer days, the dome's panels could be darkened like sunglasses to shield the city from the sun's glare. In winter, the glass would become clear again to let through the sun's rays for extra warmth.

Surrounded by protective domes, communities could be set up almost anywhere on Earth, from the frozen polar ice caps to the searing hot deserts. However hostile the conditions outside, the people inside their environment-controlled dome could lead a normal, pleasant life.

Another strange idea of Fuller's is for cities that float in the sky. Each of these aerial communities would be built within a geodesic ball a

The next important task is to build a balanced community, encouraging industry to support the venture and people to support the industry. And once the local council has played its part with commercial grants and subsidized housing, developers will move in and build private housing which will add yet more people.

HOME IN A DOME



Hutchison Library

Geodesic domes – domes that are made of interlocking shapes and can stand up without supporting beams – are already in evidence as structures in public places and exist as houses in some remote areas. They are simple to build, solid, and they are also light and airy inside.

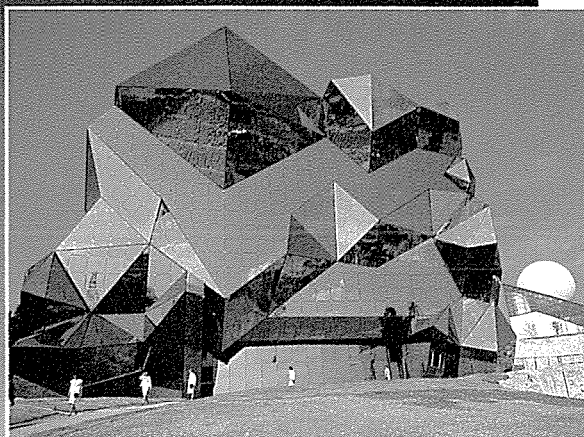
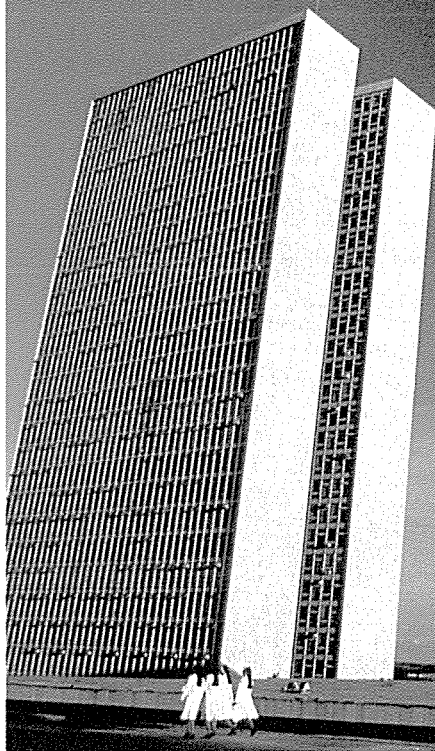
These domes, in the Arizona desert in the United States, have light-coloured surfaces to reflect the glare of the sun, and also have chimneys to keep a cool airflow inside. Their squat shape is a good protection against the tornadoes and dust-storms that can sweep across the desert.

Building Arcosanti in the middle of the Arizona desert. This complex city-structure was conceived on paper in the 1960s by Paolo Soleri, and was started in 1970. While it is now open for daily tours by enquiring visitors, this futuristic development will eventually house an experimental community in hive-like domes.



Cosanti Foundation





Poitiers, the city set on a hill above the rivers Clain and Boivre in France, has attracted invaders, settlers and visitors for centuries. Now this balcony town plays host to a huge theme park which includes 'Futuroscope', an exhibition hall focused on technology.

kilometre or more across. When the sun shone on the city-sphere, the air inside would be warmed, and would expand, so that some of it would be pushed out of openings in the ball. Then the whole structure would weigh less than the surrounding air and would lift up like a hot-air balloon. Provided the air inside remained warm, the structure would stay aloft, drifting endlessly around the Earth like a cloud.

Planetary citizens

Because of vastly improved communications and transport, the old barriers between nations are gra-

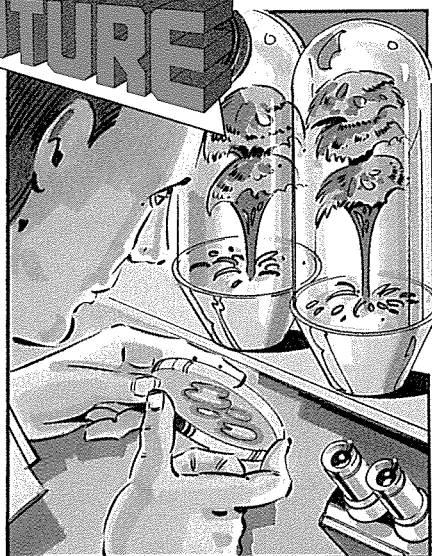
A futuristic city-shape, already in existence. Brasilia, the new capital of Brazil, was built in the 1970s from scratch in a clearing in the Amazonian jungle.

dually breaking down. Instead of belonging just to some small community, or even a large city, we are all becoming inhabitants of a 'global village'. Jetliners fly us halfway around the world in just a few hours, whereas it used to take weeks or even months to cross the ocean. By telephone or satellite television we can be instantly kept in touch with what is happening almost anywhere on the planet.

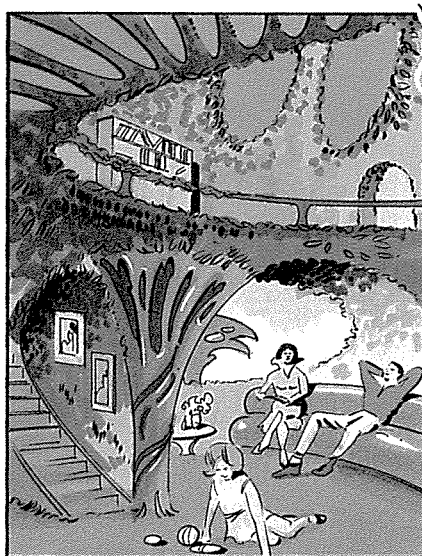


Science City, in Japan, was built to house the booming new technology industries. There is no public transport, and the 140,000 inhabitants live and work in computer-controlled environments. Schoolchildren use computers to work on, and are not forced to take any exams.

INTO THE FUTURE



▲ Genetically-engineered plants may be the houses of the future. Instead of being cut from trees, lumber could be grown in the laboratory from cultures of wood cells.



▲ From that, the engineered seeds could be planted. They will already contain all the information for creating rooms and internal walls with doors.



▲ When fully grown, the tree will become a living house. It will clean the air, recycle water and store solar energy through photosynthesis.

INCREASINGLY, MAN WILL hand over hard physical and repetitive labour to robots. These robots, however, do not resemble the almost human creatures of the movies. In fact, the majority of industrial robots bear no resemblance to Man at all.

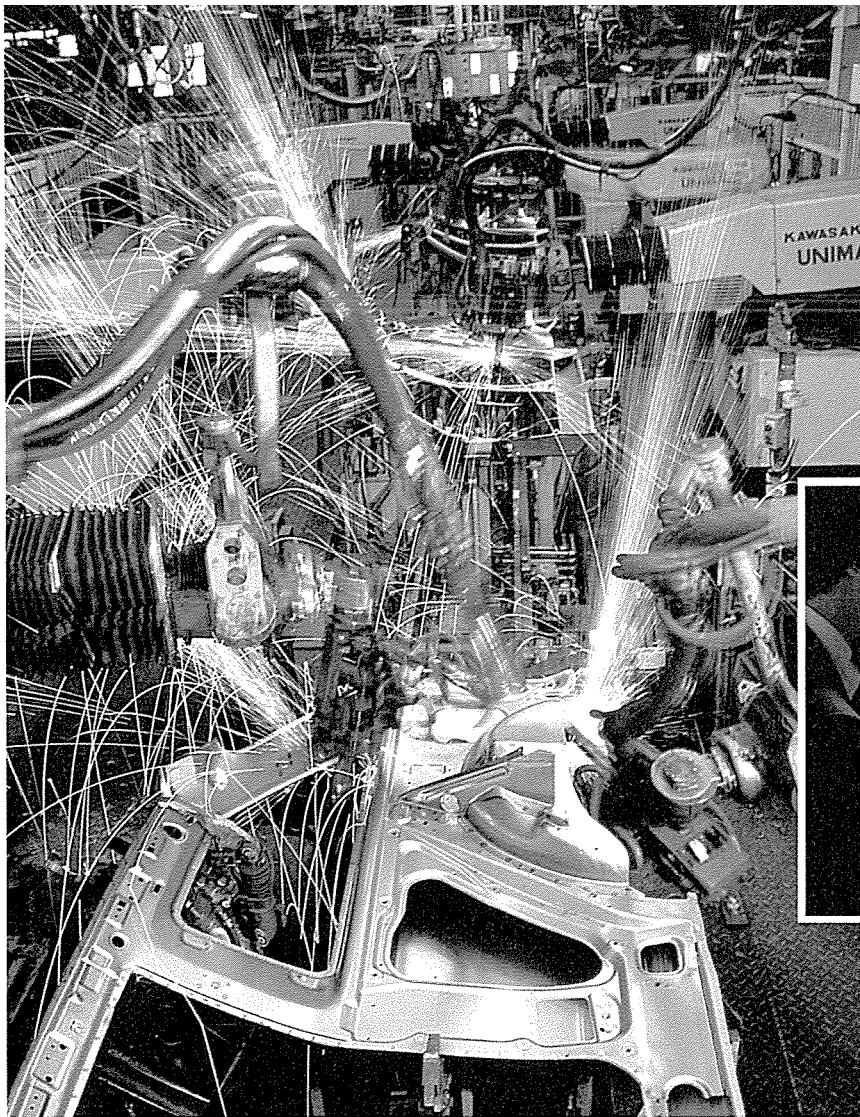
The human shape is, in fact, an inefficient pattern for carrying out mechanical work. The robot welders, assemblers and sprayers that inhabit the modern car factory consist of a power unit, a manipulating arm and a computer program. They are so-called continuous path robots — an operator will lead the robot through the operation it has to perform and the robot's 'brain' will remember each part of the movement and repeat them all, time after time. A robot welder can make up to 300 welds on a car body in a couple of minutes and never needs a tea break.

❁ Versatile robots

British Leyland is one company which uses sniffer robots to detect water leaks around the edges of windscreen and doors of cars. The car body is filled with helium and the robot then moves over every seam sniffing for the slightest

THE MAN MACHINE





and able to afford bigger apartments or a house in the country.

As well as sperm banks, life may be stored in cell banks, for future cloning by genetic engineers. As the human population increases in size, so Man is using up available land for crop use and wildlife is being pushed ever closer to extinction. No ordinary zoo could hope to begin to deal with the problems of conservation in more than a superficial way. Scientists are predicting cell-zoos where genetic material from a large proportion of known animal species

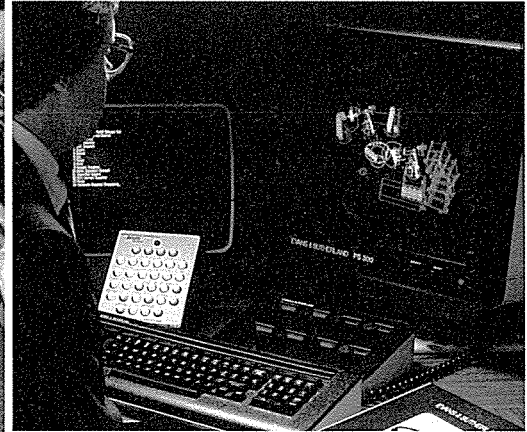
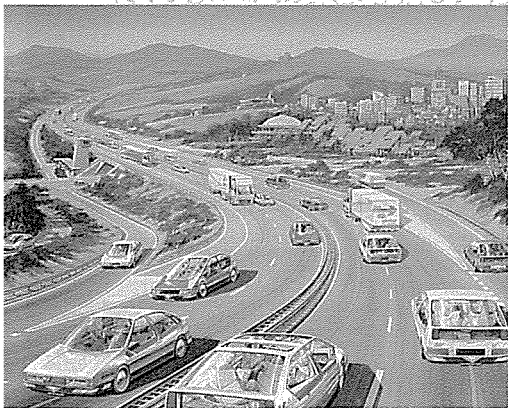


ABB Robotics Ltd

Cars are made by robots, which weld body parts together as they pass along a conveyor belt. Human labour has been virtually eliminated from most car production lines. Inset, the robots are designed on computer.

Rex Features

COMPUTER CAR 2000



Volkswagen

Cars of the future will take the stress out of driving. Cars will be installed with an electronic system, which will enable them to travel at high speed, nose to bumper, without fear of collision. As soon as the car is on the guide track on the centre of the road the driver can sit back and watch an in-car video or snooze.

Laser sensors will control the distance from the car in front and respond to underground indicators that replace traffic lights. A computer will ensure the vehicle follows a programmed route to the required destination.

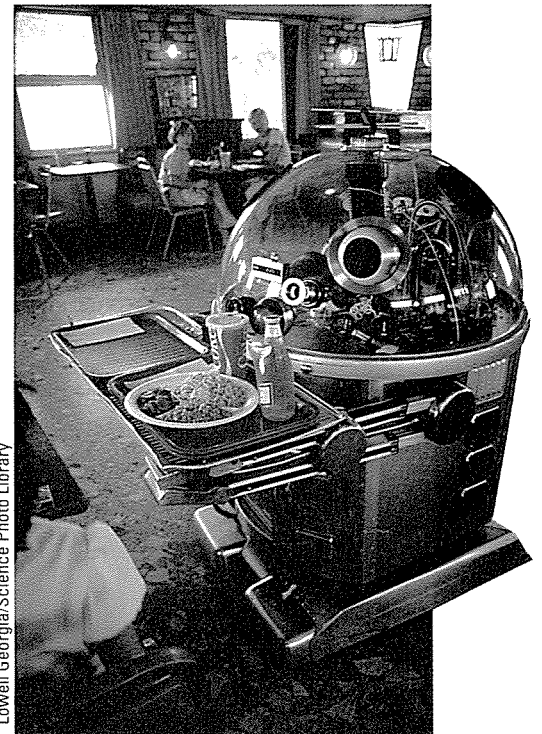
trace of gas escaping with its sensitive nose.

In the future, robots are likely to be programmable systems rather than individual, one-job units. A programmable house system will clean itself, produce meals, open and close shutters and curtains, regulate light and heat, and wake up the humans in the morning. Anything resembling a stainless steel butler in physique will be strictly to amuse visitors.

Running out of space

Robots will not be able to help humans deal with the chronic overcrowding, which is going to become a way of life for many, if predictions are true. With a world population of ten billion or so from the mid-21st century onwards and with over half this number inhabiting cities, city space will be at a premium. People may marry or live together in order to share apartments, but it will not pay them to have children. Many will wait until later in life to start families.

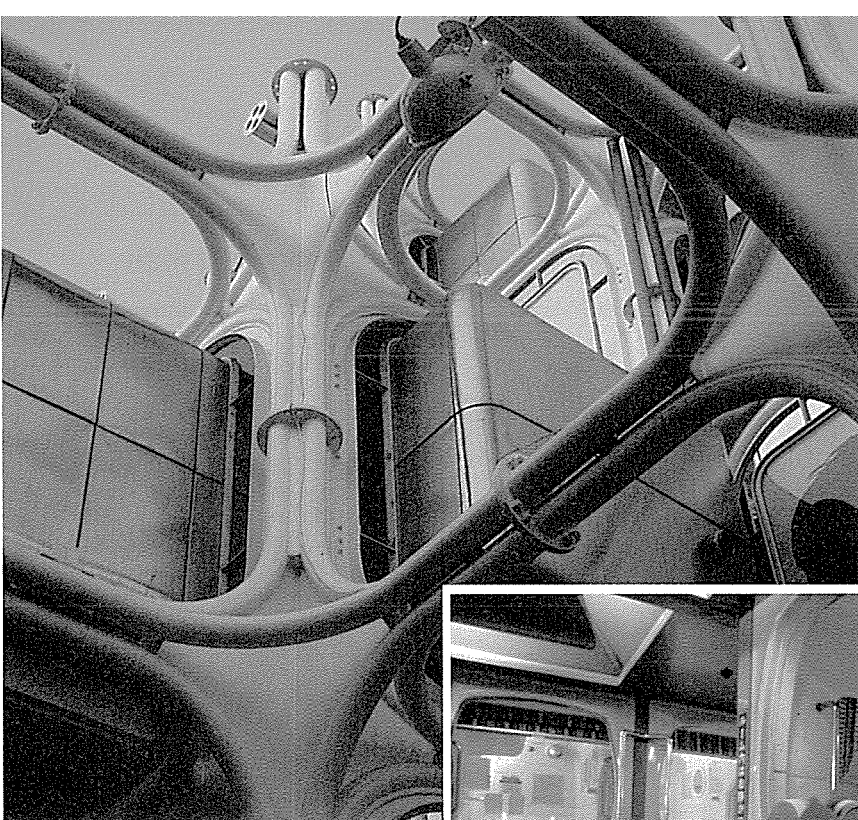
To guard against the possibility of reduced fertility, the likelihood of which increases with age, there may be an increased use of sperm banks. Young men would deposit sperm in a named account, so that it can be used when they are older,



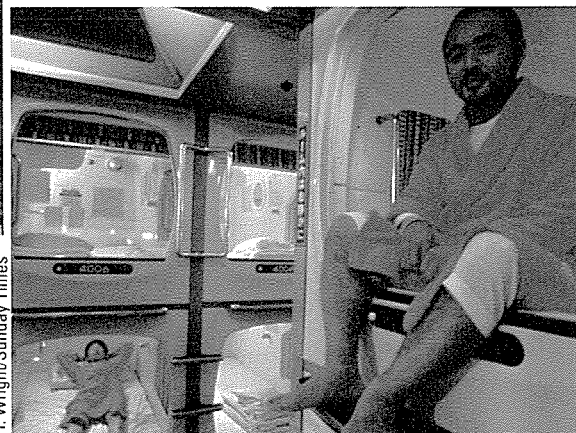
Lowell Georgia/Science Photo Library

Robot waiters always have a friendly word for customers, and never forget an order. Built-in cameras and ultrasonic rangefinders enable them to avoid bumping into people.





A prefabricated steel frame is capable of holding over a hundred dwelling units. These are factory-made with in-built bathrooms and stereos. The units are slotted into the frame as required.



L. Wright/Sunday Times

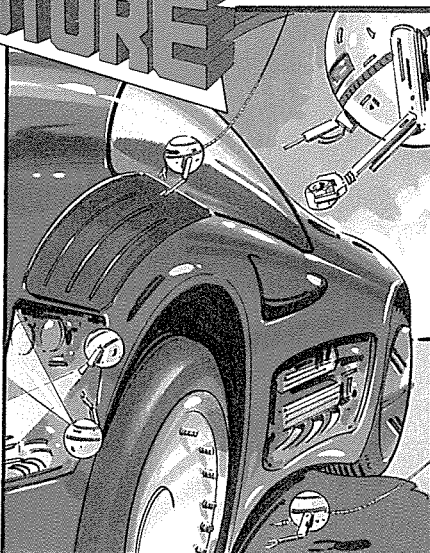
Room capsules in the New Rubia hotel in Osaka, Japan, are 183cm deep, 91cm high and 76cm wide. Made of fibreglass, they provide small but cheap accommodation for those who only require a bed for the night. The hotel management can squeeze in four times the number of guests that could be held in a conventional hotel. In return, they charge only a quarter of the price.

will be frozen and stored. If, as predicted, the human population shrinks again, from the 26th century onwards, the stored material can be used to clone entire species back into existence, and the animals will be able to return to the wild to rebuild their numbers.

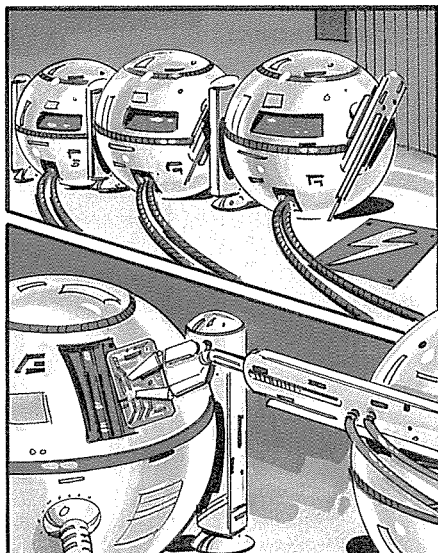
Man may adapt to the crowded urban conditions better than he imagines. The Japanese are probably the most crowded nation on Earth. The population of over 120 million lives crammed into a few coastal cities for the main part. The Japanese countryside is too wild and mountainous to support urban

sists of banks of cupboard-like sleeping units, complete with fitted radio, TV and video, hi-fi, and telephone, plus a futon bed. The room capsules are only sufficiently high to sit in, and are stacked three-high, in rows, like cells in a beehive. TV and video screens are built into the ceilings, so films can be watched by

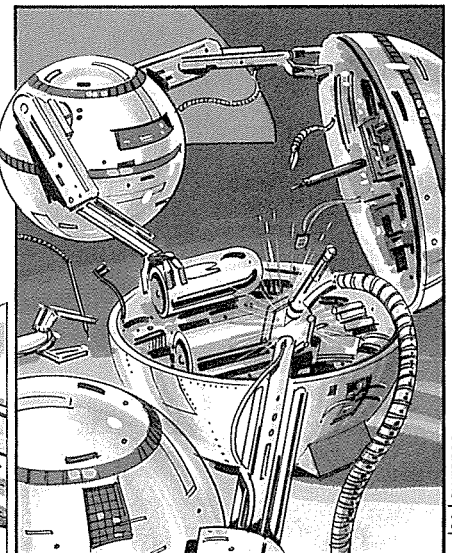
INTO THE FUTURE



▲ A microrobot will be small enough to go into car engines, electrical systems and air ducts to inspect them for faults, and to repair and clean them from the inside.



▲ When its energy runs low the microrobot plugs itself into a power supply. With the help of other robots it will clean, service and repair itself.



▲ Microrobots will be able to replicate themselves, so humans would no longer play a part in the building or maintenance of their robot helpers.

JOE LAWRENCE

MINIATURE ROBOTS



Prototype biochips have been used as chemical detectors for analyzing liquids. They transmit calculations as electrical signals, and are made of silicon and an enzyme.

Repairing man

Medical biochips could be used to transmit information from inside the human body. They could, for example, be inserted into the bloodstream and relay information on the concentrations of various substances in the blood. The medical potential for biochips is enormous. Hearing and sight might be able to be restored by sound- or light-sensitive biochips, which could send nerve-pulse messages to the brain.

The biochip is one way of overcoming the limitations of the silicon chip. With stupendous information-handling abilities, biochips could have their own learning memories. They could build up a fund of experience, which would enable them to approach ever more complex calculations, and they might even be able to create improved versions of themselves. If that happens, then Man with integral machine parts in his body might one day find himself challenged by the machine with living organisms incorporated into its make-up.

Future medicine is likely to explore an aspect of the human physiology that has long been a mystery – the effects of electric and magnetic fields on the body. A Russian scientist called Semyon Kirlian devised a method of photographing the electric field produced around objects when they are placed near a metal plate charged to a high voltage. Some people think that the Kirlian patterns formed around a human hand may somehow indicate the person's state of health. But most scientists believe that variations in the moisture content of the skin are the main cause of variations in the patterns produced.

Electro-magnetic fields applied to the body have already been used to speed up healing processes, such as the regeneration of bone tissue. And the body may use electrical effects as part of its self-healing system. If so, a way of stimulating this system to hasten healing may be discovered.

the occupants while lying down.

As Man's body becomes less muscular, literally shrinking from lack of use, he may increase its robustness with bionic armour. He could even end up as a type of cyborg – a man-machine – with original body and manufactured parts intimately connected, or even growing together. However, with his improving skills in genetic engineering, Man may be able to forestall a weakening of the body by inserting genetic material into his own cells, and keeping a strong skeleton and powerful muscularity a programmed part of the species.

Biochip revolution

Where manufactured and organic material is likely to come together most spectacularly is in the field of miniaturized information storage.

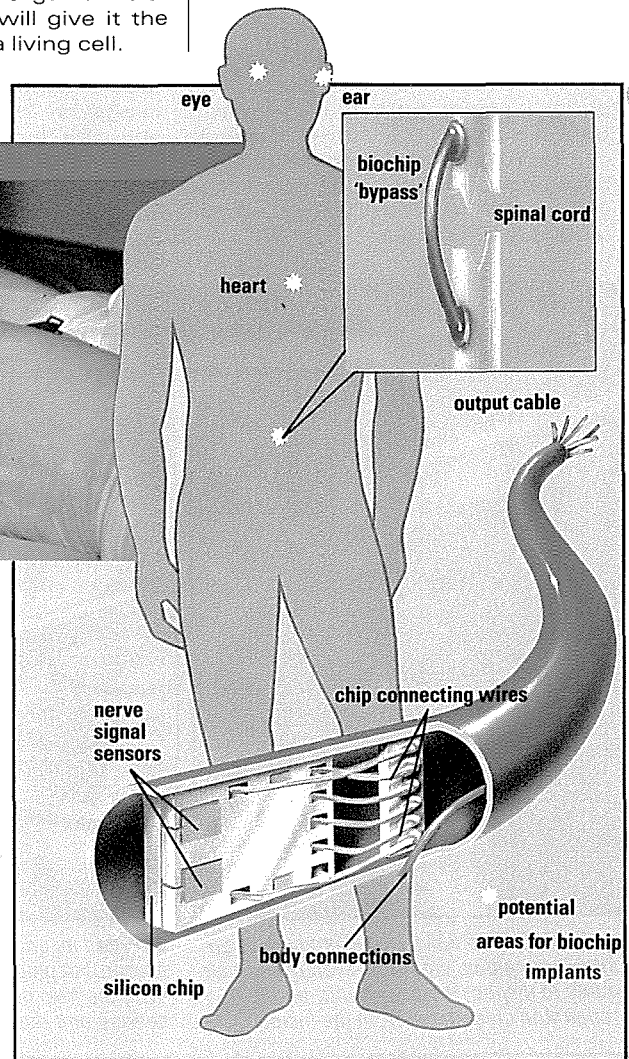
Computer scientists are excited by the idea of the biochip, a three-dimensional information chip controlled by proteins, instead of the logic gates and circuits of the standard flat silicon chip. Organic molecules in the biochip will give it the computing power of a living cell.

BODY PARTS



Gamma/Frank Spooner Pictures

Biochips placed in the body could be used to send and receive information from the nervous system. A 'bypass' of the spinal chord could restore full movement to people suffering from paralysis. Inset, blind people could be given back some measure of sight by linking photo-sensitive biochips to the visual region of the brain.

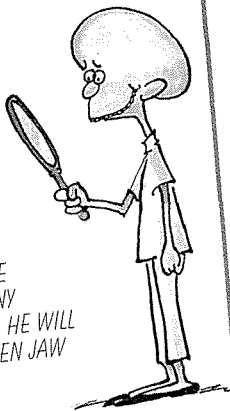


James Marfy

Just amazing!

LOSING FACE

ORTHODONTISTS RECKON THAT WITHIN A FEW MILLION YEARS MAN WILL LOOK VERY DIFFERENT. HE WILL HAVE SMOOTH SKIN, NO HAIR, AND, BECAUSE HE WILL EAT SO MANY REFINED FOODS, HE WILL HAVE A SHRUNKEN JAW AS WELL.



Paul Raymond



FLY-BY-WIRE

AIR TRAFFIC CONTROL

FLY-BY-LIGHT

FLYING COMPUTERS

Large, advanced cathode ray tube displays on the A320 have replaced the traditional dials and gauges. The Centralized Fault Display System displays diagnostic data on multi-purpose control and display units in the cockpit, and the crew is constantly fed updated data by the synoptic displays on the Electronic Centralized Aircraft Monitor (ECAM)

Airbus Industrie/APL

DOZENS OF DIALS, SWITCHES and controls confront the pilot of the latest design aeroplanes, sending out a wide range of constantly changing information, which he must sort out – sometimes within seconds.

Computers can do a great deal to help to relieve the pilot's workload. Computers are able to monitor and control engines, assess weapons systems and potential targets, and deal with navigation. Quite often they even take over and fly the aeroplane.

The European Airbus A320 is a good example of modern aviation technology. The most significant innovation is its 'fly-by-wire' control system. In a traditional airliner, the pilot and co-pilot have control col-

umns that are mechanically linked to the aircraft's various control surfaces.

The A320, on the other hand, dispenses with the mechanical links. The pilots have small control columns that send electrical signals via a computer system. Wires have replaced the mechanical links.

Computer control

The pilots' commands are interpreted by a flight computer, which then implements the appropriate changes to the control surfaces, based on its pre-programmed record of the aircraft's behaviour. Changes to the way the aircraft handles and performs can be made by amending the computer program.

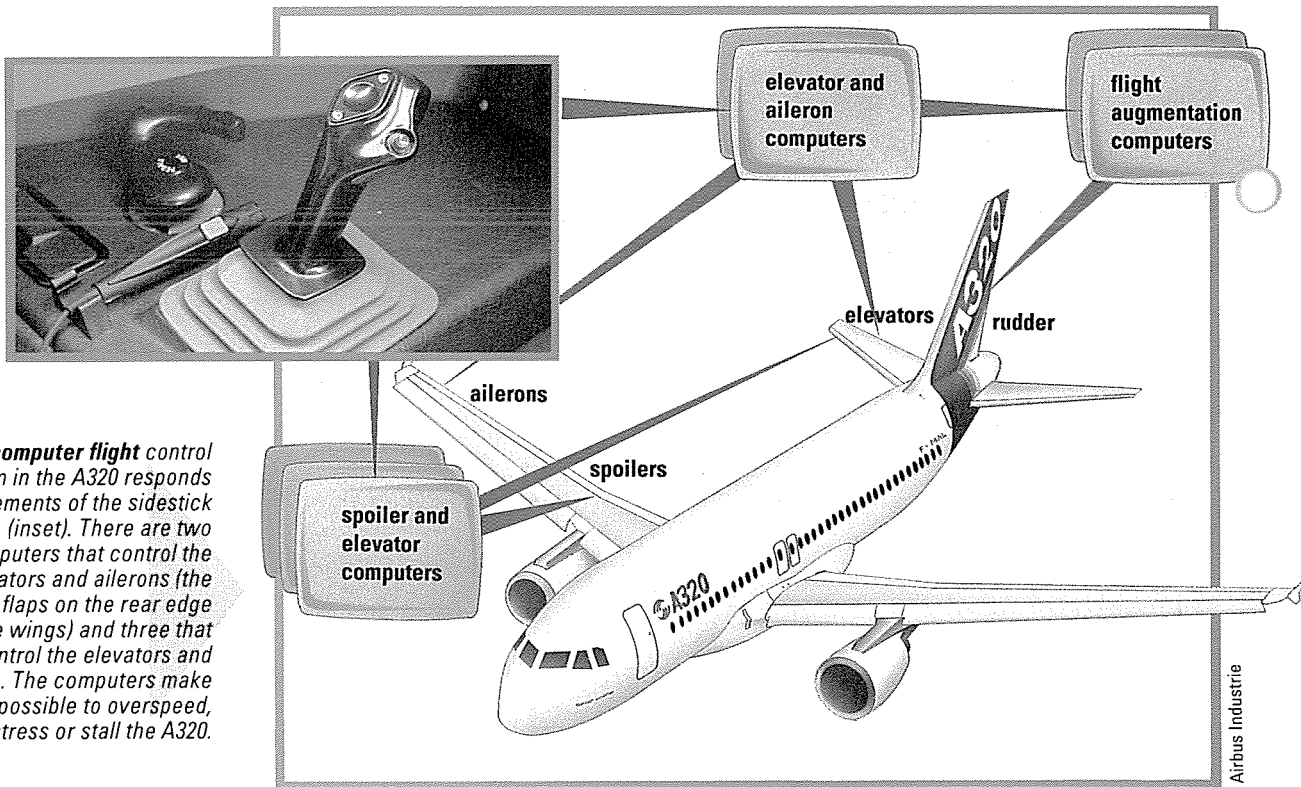
Each computer system has at least one back-up. The computer

equipment is produced by different suppliers and the programs for each computer are written by different teams. Such precautions avoid the possibility of two computers suffering the same design failure.

Computer control enables a number of sophisticated protection systems to be fitted. One of these is called the alpha-floor protection, which automatically brings in full engine power when the aircraft reaches a specified angle of attack. Another is called the alpha-limit feature, which selects the best angle of attack to generate maximum lift when the pilot climbs.

The computer control system aboard the A320 briefly fell under suspicion following the crash of an aircraft at Mulhouse, France, in June





The computer flight control system in the A320 responds to movements of the sidestick (inset). There are two computers that control the elevators and ailerons (the hinged flaps on the rear edge of the wings) and three that control the elevators and spoilers. The computers make it impossible to overspeed, overstress or stall the A320.

Airbus Industrie

1988. It now seems that pilot error was to blame. The A320 was performing a low-level fly-past at an air show, but failed to pull out of its climb quickly enough. It crashed into a forest beyond the end of the runway, killing three people. The alpha-floor protection system, which might have saved the A320, does not operate at very low altitude. Below 30 metres, the computer assumes that the aircraft is coming in to land and consequently

does not engage full power.

The A320's navigation is also handled by a computer. The system is programmed to follow the most fuel-efficient flight profile, from take-off to landing.

Current computer-assisted aircraft contain about 50 different computers and microprocessors. Each of these is allocated to a specific task or group of tasks. The aircraft of the mid-1990s and beyond may be equipped with a

Air traffic control is another area where more powerful computer systems will be needed in the future. Already, at times during the summer months, some airports are unable to cope with more flights. Powerful air traffic control computers could overcome this problem.

Air traffic control is being increasingly computerized in order to cope with the extremely heavy load of international civil aviation.

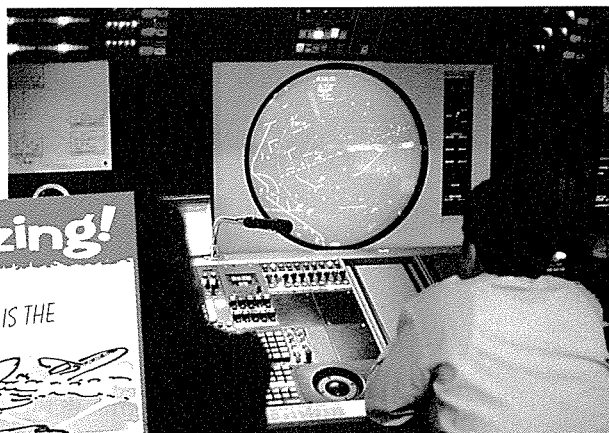
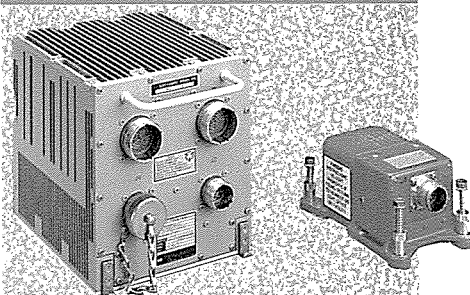


Image Bank

THE BLACK BOX

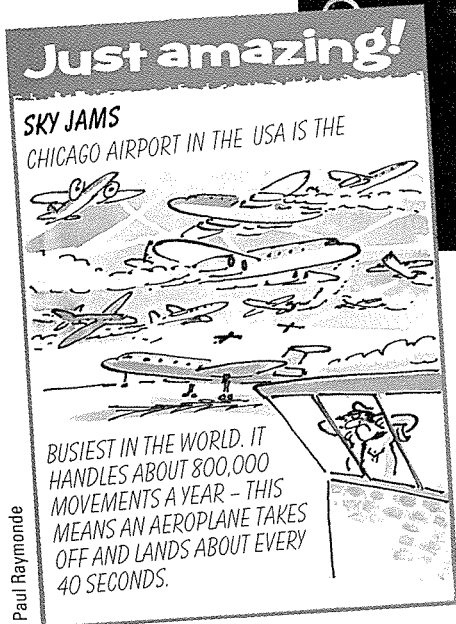


Reports of air accidents carried by the various news media often refer to the 'black box' flight recorder. This is the device that records what happened to the aircraft up to the moment just before its crash.

In fact, the term black box is inaccurate. Firstly, there are not one, but two boxes. The first is the Flight Data Recorder, or FDR, which records various instrument readings and control settings throughout the flight. The second is the cockpit voice recorder, or CVR, which records voices and other sounds in the cockpit. The instruments store 25 hours' worth of information.

Secondly, the FDR is not black at all. It is bright orange, which makes it much easier to find after a crash.

Smiths Industries



Paul Raymond



TEST PILOT

NEW AIRCRAFT DESIGN MUST be tested thoroughly before a plane leaves the ground, or is even manufactured, to avoid costly – and sometimes fatal – mistakes. Computer-aided design has now become standard practice in the aviation industry.

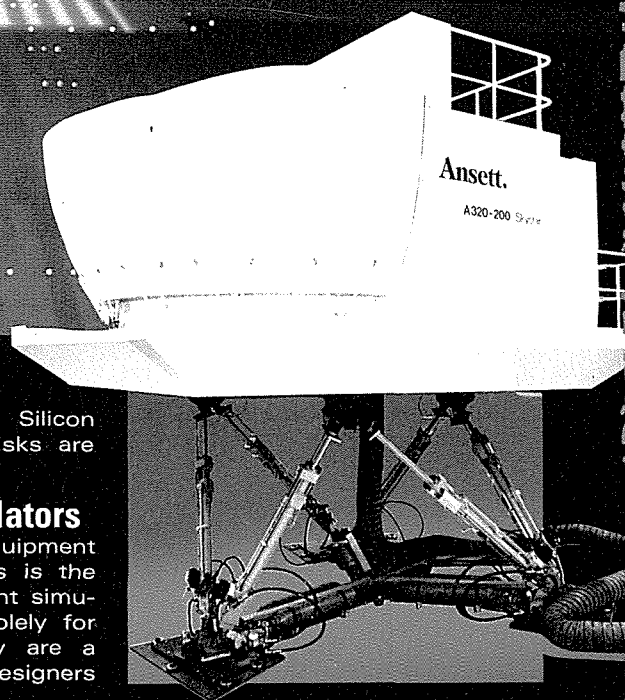
Computers and simulators are greatly assisting the old method of building model aircraft and examining their behaviour in a wind tunnel. The American manufacturer Lockheed now uses a powerful Cray X-MP/24 dual processor supercomputer to help with aircraft design. Using a technique called computational aerodynamics, the computer can quickly calculate the airflows around the aircraft.

The computer calculates the pressures and forces on various parts of the structure so that the aircraft's structural and flight characteristics can be predicted. Lockheed engineers have checked the results from the computer by wind tunnel testing of traditional models. But a single engineer's computer workstation can require a huge amount of memory. Sikorsky engineers use the 2400 Turbo desktop

workstation, supplied by Silicon Graphics. High-capacity disks are used to store all the data.

Engineering simulators

Another modern piece of equipment used by aircraft designers is the engineering simulator. Flight simulators were once used solely for training pilots. Now they are a valuable tool for aircraft designers



Computer-aided simulation is used extensively to test new aircraft design. Computers can evaluate an aircraft's flight characteristics and predict how it would react under a whole variety of circumstances without it ever leaving the ground.

Rediffusion Simulation Ltd.





Computer-aided design and manufacture (CAD/CAM) means that aeroplane engines are designed more efficiently. At Rolls Royce, the plane parts are made by micro-computer controlled automatic machines.

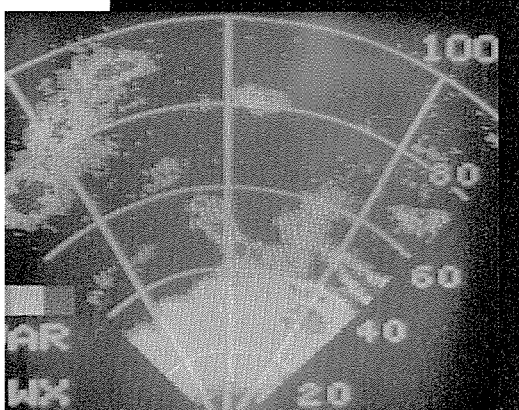
as the real thing. Often, the only way to tell that you are in a simulator is to look out of the window. Although the hardware is accurate, the view from the cockpit is usually nothing more than a cartoon-like representation of the real world.

Producing an artificial landscape and making it change in response to the movements of the simulated aircraft takes a phenomenal amount of computer power. Some of the technology used in flight simulators has much in common with arcade video games.

as well. Almost the entire process of designing an aircraft can now be handled by the computer-driven engineering simulator.

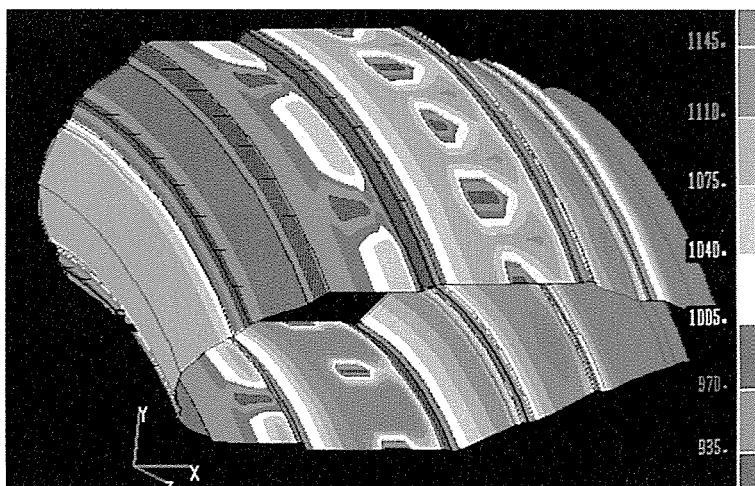
With conventional aircraft design, the last component to be added was often the pilot. Engineers had to build a full-sized prototype aircraft before a test pilot could find out how easy, or difficult, the machine was to fly. This could lead to expensive mistakes. But simulators use the pilot's comments very early in the design process.

WEATHER WATCH



Accurate weather forecasts can save airlines a lot of money. If pilots can avoid bad weather and find favourable tail winds, the savings in both time and fuel are considerable. A 1986 report from the UK Committee of Public Accounts showed that on the North Atlantic route alone, weather forecasting saves airlines £60 million every year.

In the UK, weather forecasts for civil aviation cost £17 million per year. Most of this is recovered by charging aircraft that enter UK airspace. The Meteorological Office in Bracknell, Berkshire, is responsible for Britain's weather forecasts. The Office costs about £80 million per year to run, £33 million of which is provided by the Government.



The characteristics of a proposed new aircraft can be fed into a computer that is used to drive a flight simulator. A pilot then has the chance to 'fly' the new aircraft in the simulator before the aircraft is ever built. Important design changes can, therefore, be made at an early stage.

A good example of this is the development of the Sikorsky/Boeing Vertol LHX light helicopter. Designers were not sure whether one or two pilots would be needed to fly the helicopter in certain attack modes. The simulator enabled a single pilot to attempt such attack profiles before a final design decision was made.



Cockpit control

A simulator is an expensive piece of equipment. The visual system alone can cost \$2 million for a civil aircraft simulator, and \$10 million for a military system. The main flight simulator used in the LHX development programme cost \$25 million.

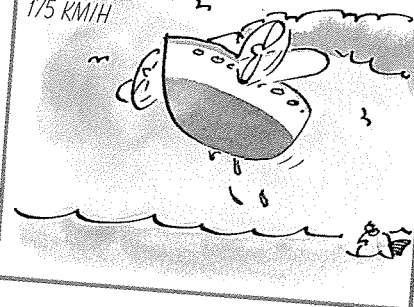
A flight simulator duplicates all aspects of a real aircraft cockpit. All of the instruments and displays are driven by a computer, but they behave in exactly the same manner

Temperature patterns in a jet engine are predicted by means of a computer simulation before the engine has been made. The predictions are later tested on the real engine by means of heat-sensitive paints.

Just amazing!

BACK TO THE DRAWING BOARD

BEFORE THE DAYS OF COMPUTER-AIDED DESIGN, THE WORLD'S LARGEST AEROPLANE WAS ALSO THE SLOWEST. WITH A WING SPAN OF 48 METRES, THE DO-X FLYING BOAT WEIGHED ALMOST 60 TONNES. BUT ITS AVERAGE SPEED WAS ONLY 175 KM/H





WEAPONS
ACK
ER HAVOC

CHEMICAL WARFARE

Ravaged trees stand as graveyard tombstones, commemorating a Brazilian forest. Chemicals sprayed to clear the land in 1984 – and they may have included 'Agent Orange', used by the USA during the Vietnam war – left at least 42 people dead.

CHEAPER AND SIMPLER THAN nuclear weapons, and without the devastating after-effects, poison gases and germ weapons have been called the 'poor man's deterrent'. Despite attempts to control them, these weapons of mass destruction could be the basis of the next arms race.

Morell/Gamma/Framestore Pictures

Most countries are signatories of the Geneva Protocol, which bans the use of chemical weapons, though not their possession. A similar agreement in 1975 banned the use of biological weapons, such as viru-

ses and toxins. Chemical weapons have been used in recent years, most notably in the war between Iraq and Iran, but also in Afghanistan by the Russians, and by the Egyptians in the Yemen in 1966-67.



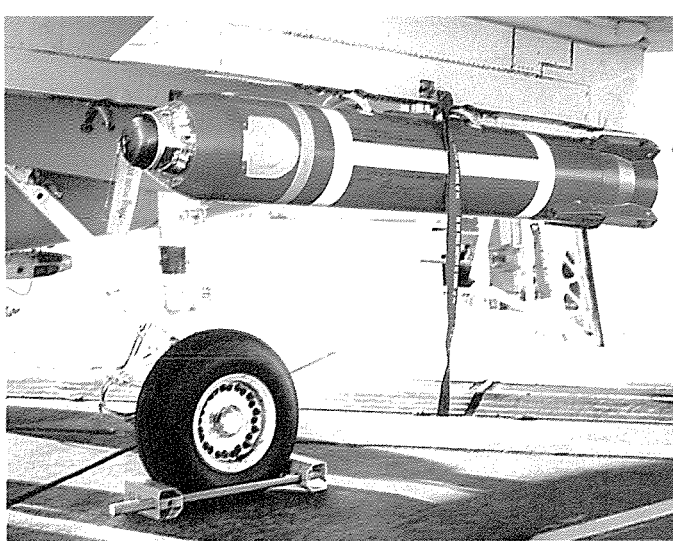
Chemical weapons

There is a wide range of chemical weapons and they work in many different ways. Some are designed to kill, some to cause temporary or permanent damage, such as skin blistering, and others, to disable people for a short time, either mentally or physically. A large enough

dose of any of them, however, will kill. Chemical weapons can also be used to kill livestock and destroy crops. They can be sprayed from planes or dropped in bombs, or put into missiles, artillery shells, grenades and landmines.

Most chemical weapons are difficult and dangerous to make, store and handle. But a new type of weapon – the binary weapon – has solved this problem. The binary weapon uses two relatively safe chemicals that react and form a dangerous one, such as the nerve gas sarin (agent GB).





***Bigeye** is an aircraft-delivered binary chemical bomb developed by the USA. It contains two non-toxic chemicals, which come together on explosion to form a persistent nerve gas.*

Nerve gases are extremely potent chemicals that attack the body's nervous system, disrupting the nerve connections between the brain and the body. They act very quickly, and breathing in only a small amount will be fatal.

The two chemicals that make up the nerve gas are kept in separate compartments of the bomb, rocket warhead or shell — they only mix to form the deadly nerve gas when the weapon is launched.

Britain abandoned chemical weapons long ago, but some countries do have them, including the USA, Russia and France. However, recent statements by these countries indicate that they are willing to give up chemical weapons. The 1991 Gulf War demonstrated that they were of limited utility. A chemical weapons convention banning both the use and possession of such weapons has been signed by many, but not all, countries.

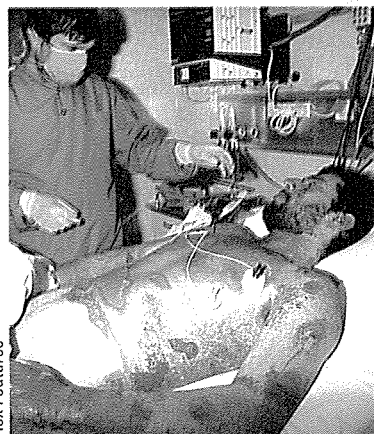
Biological warfare

Biological weapons are more strictly controlled than chemical ones. But with the coming of new techniques, such as the genetic engineering of viruses, the secret development of

sinister new weapons is a possibility.

These could include battlefield weapons, which would make enemy soldiers ill and unable to fight, but would not kill them or cause long-term injury. A potent but short-lived

FIGHTING DIRTY



Rex Features

The Iranians claim 5,000 of their men died when a single Iraqi plane dropped chemical bombs on them. Several others were wounded. Iraq has been accused consistently of using chemical weapons in spite of an international ban on them.

flu virus, sprayed from the air a few days before an attack, or dysentery-causing amoebas put into the enemy's water supply by saboteurs, could incapacitate an entire population.

Biological weapons could also be used against civilians to disrupt the enemy's economy. If they could be delivered effectively, they could wipe out a country's population as effectively as nuclear weapons, but without the destruction and radioactive fallout. The enemy could then take over the country intact, sending in troops in protective clothing to deal with any survivors.

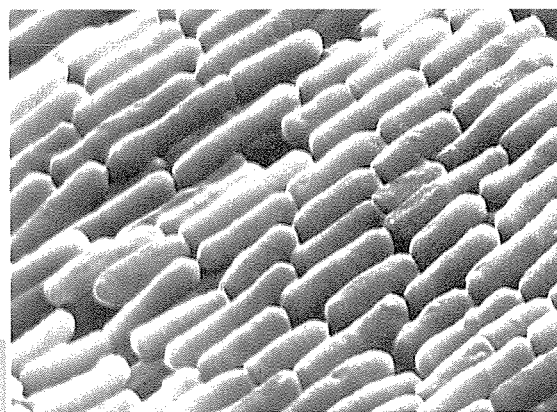
Crop attack

On a longer term basis, chemical or biological warfare could destroy a country's food supply. It could be used openly during a conventional war, for example, by spraying crops with herbicide. Or it could be used as a form of economic warfare, by contaminating crops with plant diseases, such as wheat rust, or infecting cattle with foot-and-mouth disease over several years.

Weather control can also be used to cause drought or floods, though the technology barely exists at present. Clouds can be sprinkled with silver iodine crystals to trigger off rainfall, but the technique is only partly successful. By making clouds release rain before they reached a country's borders, it would be possible to reduce its rainfall at a crucial point in its crop-growing season.

However, new weather control techniques might be developed and could be used for hostile as well as peaceful purposes. This possibility is taken so seriously that an international treaty was signed in 1978 outlawing the military or hostile use of weather control and 'environmental modification techniques'.

CNR/SPL



***Secret research** on biological warfare, carried out by the Government in 1942, left the Scottish island of Gruinard ravaged by the anthrax virus (right). Anthrax results in pneumonia and pustulent sores, so the island was declared out of bounds for 46 years.*



TRH

Just amazing!

PEACE MAN!

LSD — THE 'ACID' TAKEN BY MANY PROTESTORS AGAINST WAR IN THE '70S — COULD ITSELF BE USED AS A CHEMICAL WEAPON. ENEMY TROOPS SPRAYED WITH IT WOULD BE TOO 'STONED' TO FIGHT BACK.



Paul Raymond



IF THE BOMB FALLS...

Los Alamos National Laboratory/SPL Inset DOD/TRH



Devastation follows a nuclear blast. In August 1945, Hiroshima was reduced to a pile of rubble (inset). Many who survived the explosion died later of radiation.

The world has lived in fear of nuclear war ever since the first atomic bomb fell on Hiroshima in 1945. If the fear of global warfare has receded since the end of the Cold War, the threat of nuclear attack remains as potent as ever.

The horrific estimates of millions of dead and injured which it is believed would follow a major nuclear strike are based on the aftermath of the only two atomic bombs ever used on human targets, those dropped on Hiroshima and Nagasaki to end World War II. The Hiroshima bomb killed 140,000 people when it exploded. Tens of thousands more died in later years from the delayed, but lethal, effects of radiation exposure.

These devastating results were caused by relatively primitive bombs with an explosive power of 12.5 kilotons, the same as that of 12,500 tons of TNT. Modern warheads are far more powerful with 750 kilotons being usual. The American Trident II D5 missile, now banned by international agreement, could carry up to 15 individual 335 kiloton warheads,

a total of over 5 megatons (a megaton is a thousand kilotons).

Worst Scenario

The worst Cold War scenario involved international tension building up between the USA and the USSR. If one side felt sufficiently threatened, it might launch a pre-emptive strike. The aim would be to hit the enemy so hard with one attack that it could not strike back. But if the side under attack had enough time to launch all its missiles and bombers in retaliation, both sides would suffer appalling casualties.

The survivors of the Hiroshima and Nagasaki bombs were fortunate that they lived in a country otherwise untouched by nuclear weapons. Food, shelter and medical care was provided from elsewhere in Japan. The survivors of an all-out nuclear war would not be so lucky. In such a war between the superpowers, Britain could have been attacked with a total of 300 megatons of nuclear weapons. An attack of this size could destroy or damage about two-thirds of all the buildings, kill or injure many millions of people and cause

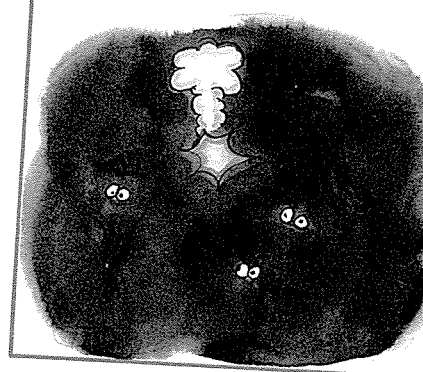
fires over about a quarter of the country. On top of all that, the whole country would be contaminated by dangerous levels of radioactivity.

With the emergency services effectively destroyed, medical and food aid would not exist and the wounded would have simply died. Food stores might have been so contaminated by radiation as to be poisonous, causing widespread starvation among the survivors.

Just amazing!

LIGHTS OUT!

THE ELECTROMAGNETIC PULSE FROM A 1-MEGATON TEST EXPLOSION 400 KM ABOVE A PACIFIC ISLAND FUSED ALL THE LIGHTS IN HAWAII. 1,300 KM AWAY.

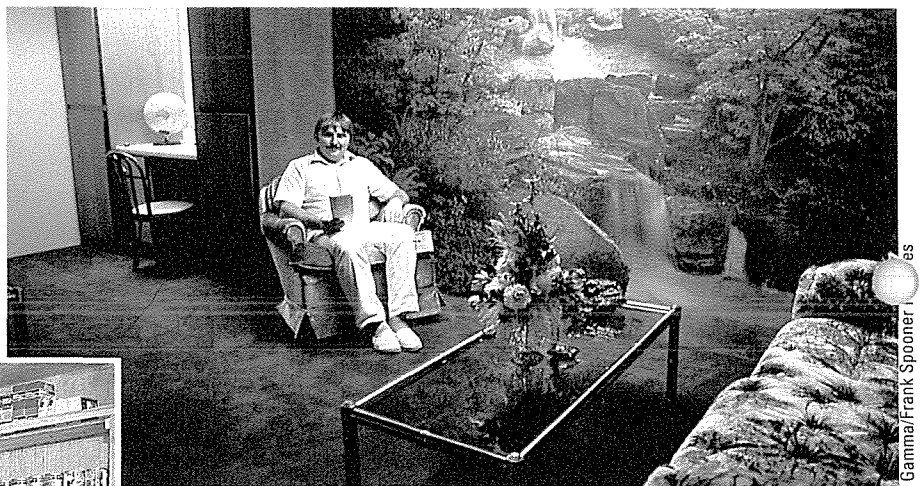


Paul Raymond

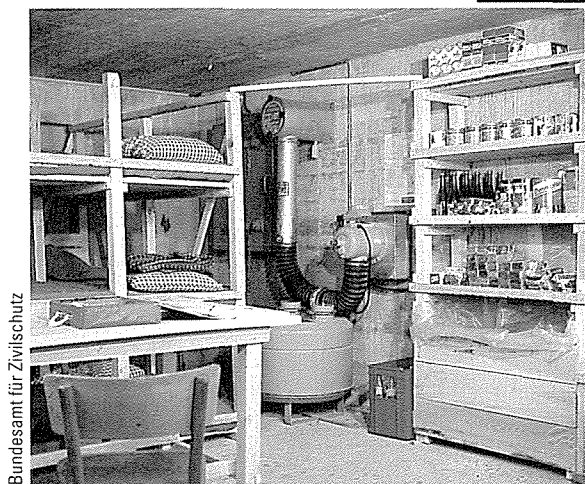


Nuclear Winter

The vast quantities of dust and smoke caused by widespread nuclear explosions in the warring nations would have risen into the upper atmosphere, blocking out the sunlight. If enough weapons were detonated this huge cloud would have drifted around the globe within



Gamma/Frank Spooner



Bundesamt für Zivilschutz

Designer nuclear shelters may be popular for the well-heeled in the USA. But the Swiss who want to provide protection for everyone, have opted for the more utilitarian version (left).

Protective clothing is vital to deal with nuclear fallout.

two weeks, bringing darkness, winter and radioactive fallout to the world.

Temperatures would have dropped by about 20°C, and all the normal weather patterns would have been changed, bringing drought to some areas and floods to others. Plants not already killed by explosion, radiation, fire, cold, drought or flood would not have got enough light to grow, and crops would have failed all round the world. Cold, sick, scared and hungry, the human race would have faced extinction.



Gamma/Frank Spooner Pictures

have long disputed the border region of Kashmir. The dispute has led to war in the past and bad feeling remains between the two nations. It is thought that both India and Pakistan are developing the technology needed to create weapons-grade uranium. Any future war over Kashmir might turn nuclear, devastating the region. However, the same deterrent effect which stopped America and the Soviet Union from launching their weapons may inhibit India and Pakistan from using theirs.

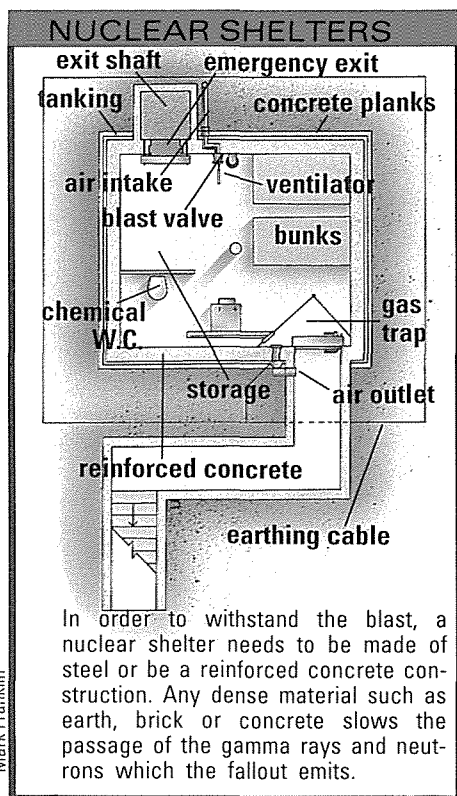
More alarming is the possibility that unstable or aggressive governments may gain control of nuclear weapons. Iraqi scientists working on developing nuclear power stations have been diverted to creating nuclear weapons. President Saddam Hussein is thought to be unpredictable enough to use such a weapon. He used banned chemical weapons during his war with Iran in the 1980s. United Nations monitors tried to dismantle Iraqi nuclear technology following the Gulf War of 1991, but it is unclear how far they succeeded.

President Gaddafi of Libya is another dictator with the potential for developing atomic weapons. Libya's links to various terrorist groups around the world make this a particularly worrying development.

South Africa is also thought to be close to gaining primitive atomic weapons, if it has not already done so. The continuing political uncertainty in that nation is destabilising the region and makes it unclear who will eventually gain control of the military, together with any nuclear technology.

Even more alarming is the fact that may Soviet nuclear weapons were based in areas of the Soviet Union now breaking away from Russia. Some regimes which have gained control are notoriously unstable and dictatorial. One republic is reported to have been taken over by a criminal gang. It is a worrying possibility that such governments may sell missiles and bombs to Third World nations for much needed cash.

Proliferation threatens to put nuclear weapons into the hands of those more likely to use them than were the super powers during the Cold War.



Mark Franklin

Since the collapse of Communism in Central Europe and the continuing disintegration of the former Soviet Union, such a catastrophic worldwide nuclear war has become increasingly unlikely. However, to the surprise of some, nuclear war itself has become more likely.

Proliferation

Known as proliferation, the spread of nuclear weapons to other countries is the major threat facing the world today. Many governments have signed treaties promising not to acquire nuclear weapons, in return for other technological aid. However, there remain several potential flashpoints throughout the world.

One of the more potent of these is in southern Asia. India and Pakistan





Terence Moore/Susan Griggs

MAN HAS ALWAYS DREAMED of making deserts bloom, and growing foods where there were only barren sands. As traditional farmlands become increasingly overworked, the agricultural future may lie in reclaiming the deserts.

A project on the arid La Mancha plain of Spain combines a unique solar energy experiment with a new concept in 'greenhouse' cultivation. A towering 'solar chimney' is surrounded by a large area of the La Mancha plain roofed over with light-permeable plastic. Heat collecting under this massive greenhouse panel rushes up the chimney at night as the outside air cools, driving turbines that generate electricity. Crops grown under the huge canopy benefit from a hot, moist

atmosphere during the day, and during cold seasons and periods of cold weather, heat levels in the growing area can be boosted from the stored electricity generated by the solar chimney.

Synthesized foods

Many scientists see the future of bulk food supplies being secured by an entirely new range of synthesized foods. It is now perfectly possible to reproduce the enzyme processes by which a cow converts grass into milk in the laboratory. A mechanically chewed 'cud' of vegetable matter can be filtered down through a succession of layers of fixed-bed enzymes — synthetic copies of the enzymes formed in the cow's body by its metabolism. The vegetable matter

A nutrient mist provides food and water for the spinach being cultivated on the walls of this plastic drum. The drum revolves slowly so that all the plants receive the same amounts of light and gravity.

goes through the same sequence of changes that occur naturally in the dairy cow, emerging at the end of the process as milk.

Leaf protein

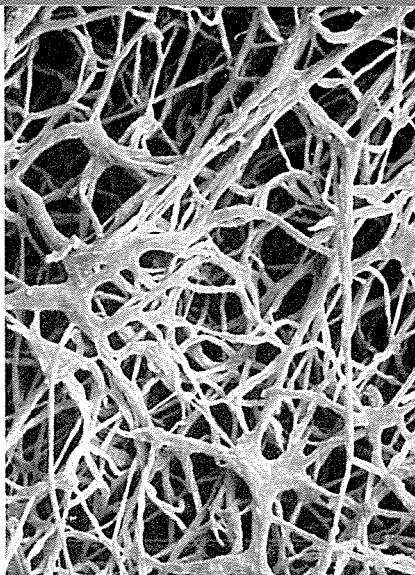
Natural fodder can also be used to produce proteins by a different method, breaking them down mechanically so that cell-walls and membranes are ruptured, releasing the cytoplasm that contains the plant's proteins. The protein-rich leaf-juice can then be transformed into the required form by further refining, ending up as a powder, if required, which can be added to other foods.

This leaf protein concentrate (LPC) can be extracted from a huge variety of sources, perhaps even the wild grass and forest-lands of the world. These are potential protein-factories, many times more efficient than the animals used to convert grass into meat.

Another great advantage of the LPC processes is that they can be applied to vegetable matter currently wasted during normal cropping of vegetables such as peas, beans, and root-crops, where the leafy vegetation is discarded. It has been estimated that as much as half the

MAXIMIZING PROTEIN SOURCES

Myco-protein, sometimes described as a distant relative of the mushroom, is produced by fungi. These plants are also the source of many useful and unusual drugs. The protein, which is tasteless, can be artificially flavoured to taste like any meat or poultry; it is low-fat and has the same amount of dietary fibre as fresh green vegetables. The long growing threads called mycelia (seen here through an electron microscope) are woven into a basic fibre which is transformed into meat analogues — items that closely resemble familiar foods such as chicken or beef. This is now on sale in many supermarkets.



Dr. Tony Brain/SPL



Just amazing!

FUELLING UP

SCIENTISTS BELIEVE THAT ONE DAY PETROL COULD FILL OUR STOMACHS AS WELL AS OUR CARS. A BACTERIA WHICH GROWS ON PETROLEUM IS NOW BEING INVESTIGATED AS A POSSIBLE SOURCE OF PROTEIN.



Paul Raymond

protein in a crop is wasted in this manner. The main problem with LPC is in getting people to try something new. In most people's minds 'greenburgers' belong to science fiction.

Utilizing bacteria

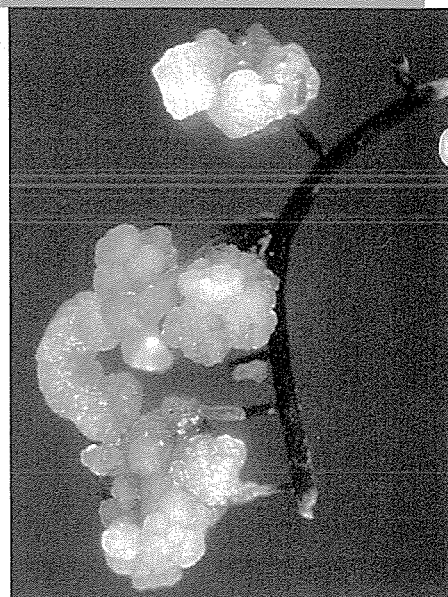
Yeast and bacteria can be cultivated and have been used commercially to produce animal feeds. One advantage of feeding yeast and bacteria proteins to livestock is that the huge amounts of fish, soya and oil-seed, which produce expensive animal proteins, would then be free for human consumption.

Replicating resistance

The resistance of plants to disease is often conferred by a single gene, which scientists hope to transfer from plants bearing it, to those that are without it. Some genetic im-

CLONING PLANTS FOR MAXIMUM YIELD

Research scientists are now using tissue culture techniques to grow clones of a parent plant in an attempt to increase the yield of various crops. One of the first examples of successful cloning involved the oil palm. Samples of root were taken from a high yielding oil palm and placed in a special nutrient solution. The cells of the root began to multiply and formed a mass known as a callus (right). From this callus, tiny oil palm plants began to grow. These were transferred to individual test tubes and kept in a controlled environment; the fledgling plants were fed the various nutrients required at different stages of their growth. The young plants were removed from the test tubes, but kept indoors until they were firmly established, then they were transferred to special growing bags outdoors until ready for planting in the fields.



Unilever

provements are achieved by transferring resistances in one variety to other varieties of the same plant. Successful gene splitting and implantation might well produce insect-free commercially grown vegetables in the future.

Cell fusion

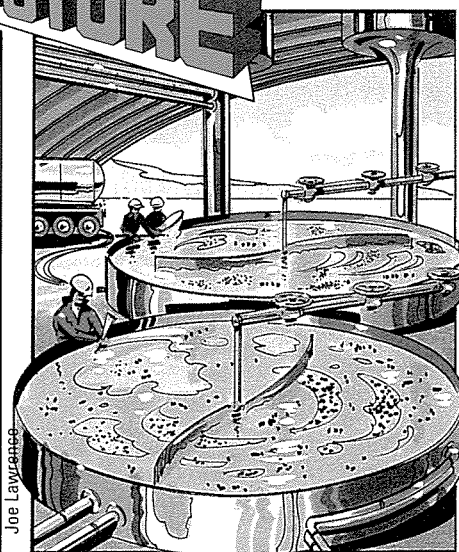
Related species, such as the tomato and the potato, have been subjected to cell-fusion to produce hybrids known as pomatoes or topatoes. First examples produced neither good tomatoes nor good potatoes, but when the techniques have been refined, a single plant will produce food above and below ground at the same time. Further fusions might be possible between

crop plants and succulents, such as pineapples and cacti, which use a tenth of the water employed by other plants to produce an equivalent amount of dry weight. If succulent metabolism, which enables these plants to keep leaf pores closed during the day, could be transferred to wheat, for example, the wheat-growing areas of the world could be enlarged by 300–400 per cent.

The breakthrough most plant scientists are eager to see is the introduction into conventional crops of the ability to fix nitrogen. Only certain leguminous plants can do this naturally. This will enable high-yielding crops to be grown without nitrogen fertilizers.

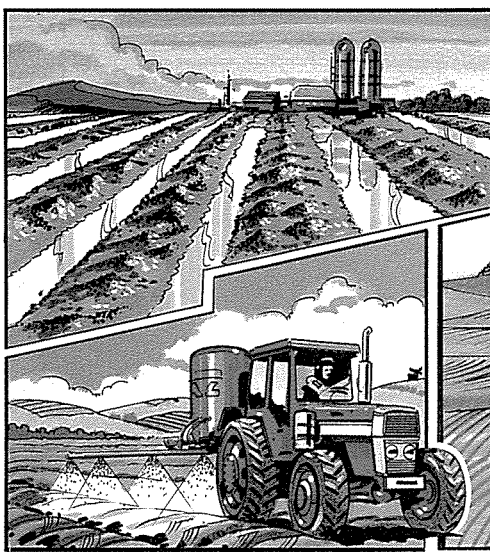
INTO THE FUTURE

BEATING THE DESERT



Joe Lawrence

▲ Growing microscopic plants called algae in water tanks could stop the advance of the Sahara Desert and make its fringes fertile.

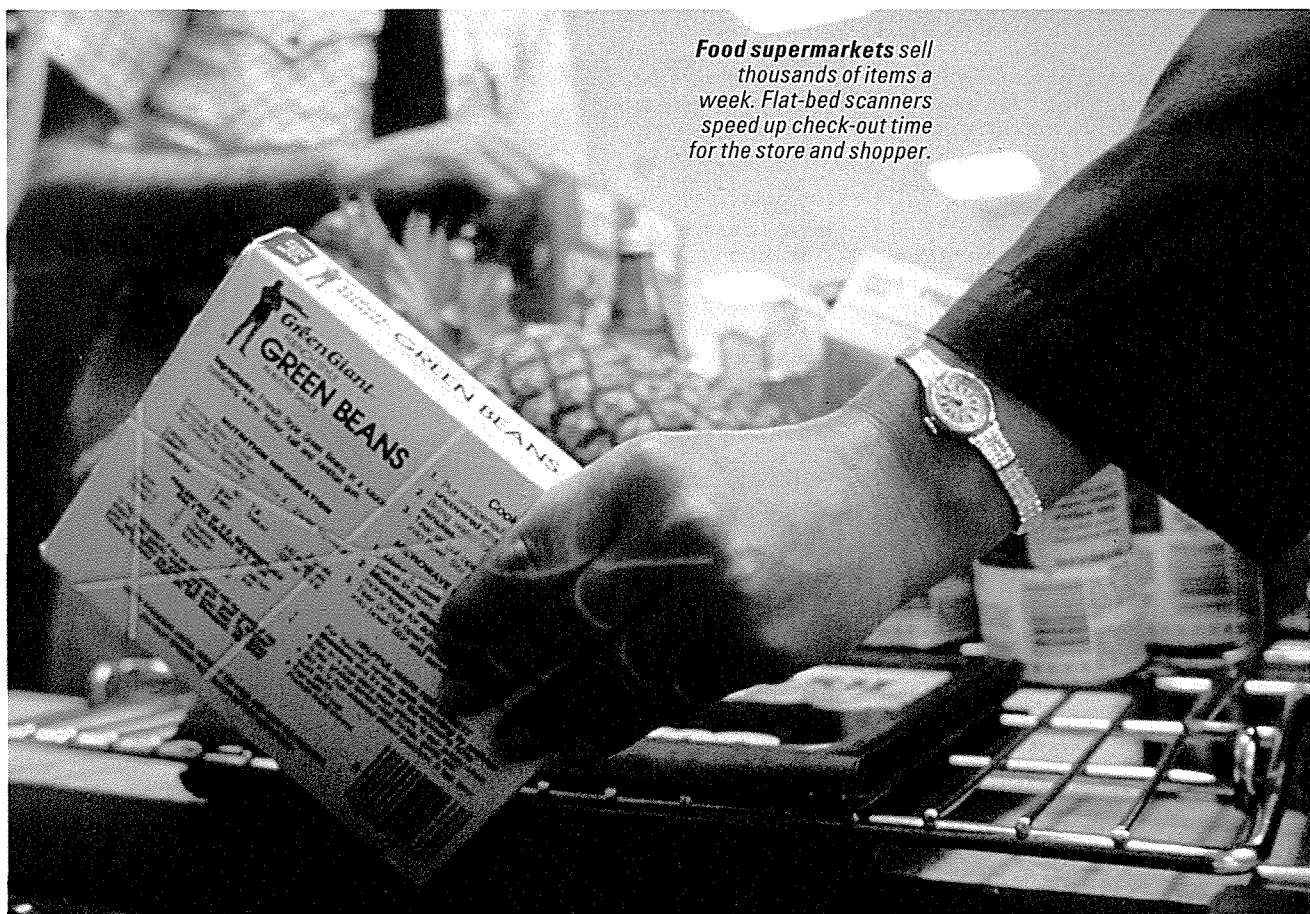


▲ The algae could be fermented in canals to produce methane gas and the remaining sludge used as fertilizer for farming projects.



▲ Trees could be encouraged to grow around the desert edges and their presence might eventually increase local rainfall levels.

SUPERMARKET 2000



Food supermarkets sell thousands of items a week. Flat-bed scanners speed up check-out time for the store and shopper.

Pau Shambroom/SPL

-  **BAR CODING**
-  **FLAT-BED SCANNER**
-  **INTEGRATED CHIPS**

IT'S NOT ONLY SERGEANTS and corporals who wear stripes these days – canned and packaged food have got into the act as well now they are all marked with bar codes.

Bar codes are the vertical stripes printed on the back of nearly all packaged food items and form the basis of the systems that are used in most supermarkets. These patches of black stripes started to appear in the early 1980s and have now spread to 99 per cent of manufactured food items.

The bar code gives a unique identity to each different product and to each different size of the product. In food supermarkets, the code is read by a flat bed scanner sunk into the surface of the check-out. The items in the customer's

basket or trolley are placed on the surface of the check-out, then passed over the scanner head one-by-one. The goods must all be aligned so that the bar code passes directly over the scanner.

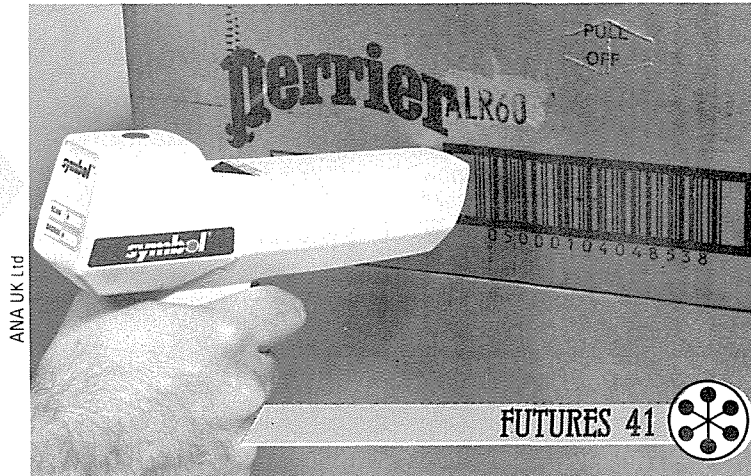
Provided that the bar code has been drawn accurately in the first place and the stripes are the standard depth, the scanner can read the code at any angle and get it right nearly 100 per cent of the time. When the bar code passes over the

scanner, the stripes are translated into eight or 13 figure numbers and are passed to a micro-computer built into the check-out till.

Ringing the changes

The price of each item of food can change many times in a year. In the past, each item on the shelves had to be relabelled every time. With the bar code system, the till computer uses the information from the bar code to look up the price in its

A hand-held reader translates the bar codes printed on the outside of many delivery cartons. The information is recorded inside the bar code reader, then transmitted to the central stock control computer at the close of business when phone costs are low.



HOW A BAR CODE IS MADE UP

ANA UK Ltd.

5 0



5 012345

The first two numbers in a bar code indicate the country of issue. The next five identify the company selling the particular food item. The block of five numbers after that describes the product. The final number is a check that the code is correct using the sum and difference method.

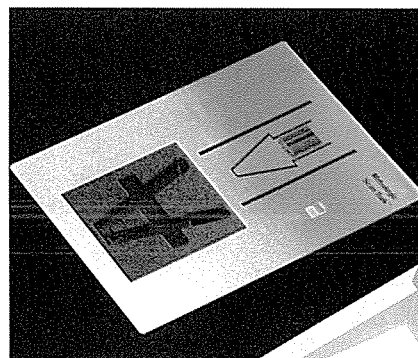


5 012345 67890



5 012345 678900

There are a million million different combinations of bar code stripes so a bar code reader (right) must work very accurately. The latest readers achieve close to 100 per cent accuracy if the bar code is well printed.



memory. This is known as the Price Look Up (PLU) facility. The price is then flashed up on the till display and printed out on the till receipt. Prices can be changed by simply feeding fresh information into the till computer.

This can be done at the store level, but when the till computer is connected to a main-frame computer at the supermarket Head Office, one instruction to the main frame can change the price in every branch in the country.

In some American supermarkets, the price is announced through a speaker at the same time as it appears on the visual read-out. This helps the customer check the price is right.

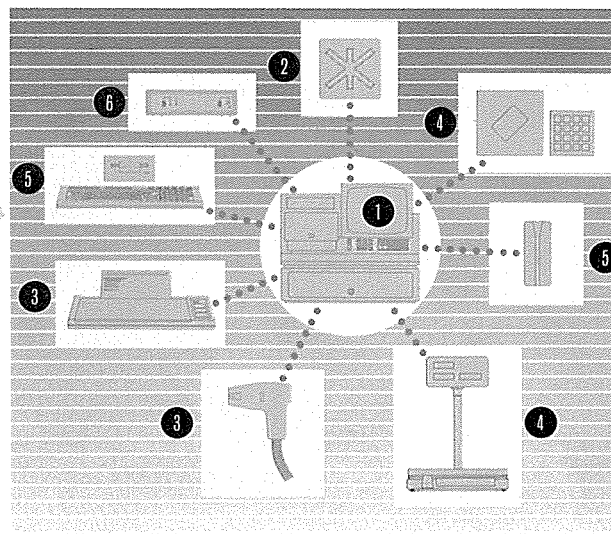
Stocking systems

Most stores using scanners have tills that are connected to a Head Office main-frame computer. This enables the main-frame to tick off the goods that are sold at the check-outs against the stocks recorded at Head Office. When a pre-determined stock level is reached, fresh supplies are ordered from the manufacturer just in time to prevent each particular branch from running out. This avoids food sitting around in supermarket warehouses.

Bar codes are also printed on the cardboard boxes that manufactured food is packed in. When the boxes are unloaded from the delivery lorry at the supermarket, these extra-long codes are read with a hand-

An Integrated Retailing System has several peripherals connected to a micro-computer.

- 1 Sentinel till with micro-computer and Electronic Funds Transfer facilities
- 2 Flat-bed scanner
- 3 Micro-computer and bar-code reader for stock control
- 4 Weighing machines with facility to issue bar coded labels
- 5 EFTPOS terminal
- 6 Modern data link



held reader. This may be connected by wire to a mini-computer in the supermarket; alternatively, it records the data on tape so that it can be relayed to the Head Office main-frame later.

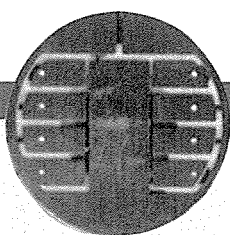
These bar codes do not just indicate the type of goods in the box, they also indicate the quantities as well. The recorded information is used to keep stock records up-to-date, without any need for paperwork. If a scanner check-out with a micro-computer in the till is connected to a Head Office main-frame and if delivery and stock information is fed into the Head Office as well, then one overall computer system is able to control all the activities of a whole supermarket chain.

In an integrated retailing system, already in use in some countries, a fully electronic payment system works alongside the electronic till. Using the EFTPOS concept, the customer presents a plastic card at the check-out. This is inserted into a terminal which reads off various data and account details about the cardholder. If the information is acceptable to the computerised terminal, the EFTPOS will allow the sale to go ahead, the amount of the bill being deducted either from credit points stored on the card or from the cardholder's bank account.

Electronic sales

Sales information is stored in the memory until the EFTPOS terminal calls up the main-frame to run a check on a customer, or until after midnight when it is cheaper to send the data along telephone lines. When the information reaches the computer where the customer's account is held, the money is transferred to the supermarket's account.

In France three million smart cards are already in use. Each card contains a tiny silicon chip which acts as a microprocessor when fed into the EFTPOS terminal. In Britain, the EFTPOS concept uses the magnetised strip on plastic cards, a technology already used by credit cards and automatic bank cash withdrawal cards. The standard magnetised strip can contain two lines of information, though later versions may be able to hold far more information.



The Bull CP8 Smart Card has a memory chip with details of the user's credit worthiness - this is automatically checked at the till without delay. The bill is charged to the card holder's account on the same day.

Honeywell Bull

SMART MONEY

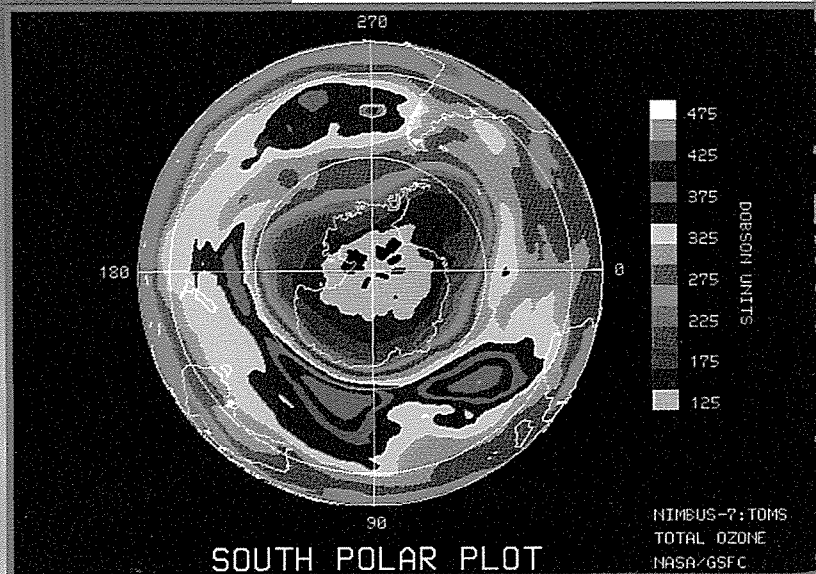
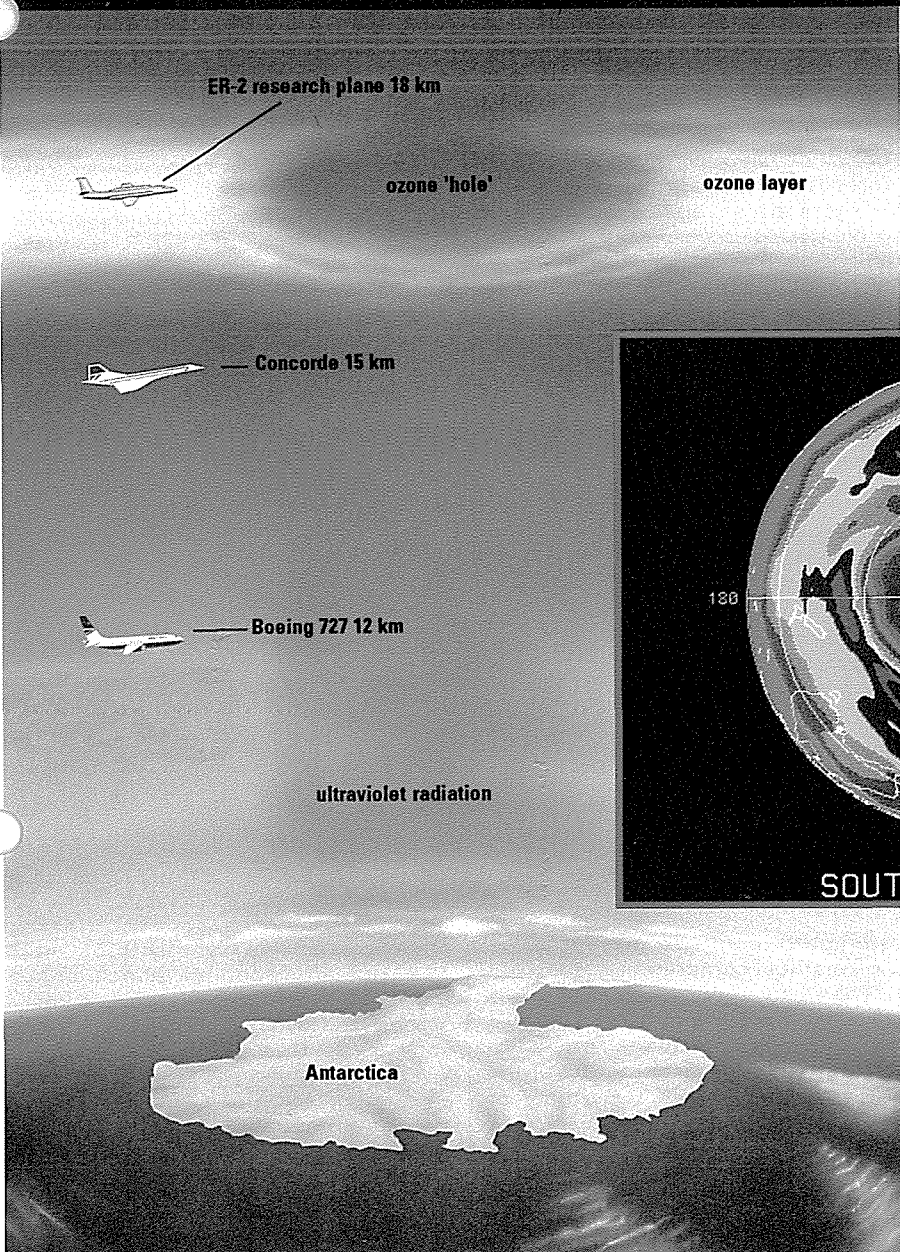


100 UNITES D'UTILISATION



MANIPULATING

Weather



Sunny weather may become a bane if the ozone layer is further damaged by human pollution, allowing more UV light to reach the ground. Already a 'hole' appears over Antarctica in the southern spring, showing up as the purple-bounded area in the satellite map (inset above).

able topsoil from being blown away. Trees also give out large amounts of water vapour from their leaves and this can moisten the air sufficiently to increase the rainfall locally. On the arid eastern side of the Mediterranean island of Crete, for example, the Greek government

HUMAN BEINGS MANIPULATE the weather both intentionally and unintentionally. So far, people have done little of the former but, potentially, a great deal of the latter. A growing number of scientists fear that our industrial activity will change weather and climate — with disastrous effects.

To date, most attempts to make a short-term change in the weather have been confined to 'seeding' clouds by scattering crystals of silver iodide into them. This can cause rain to fall. The crystals act as 'condensation nuclei' on which tiny water droplets form. These then collide, forming larger drops that fall as rain.

This technique has also been used

to try to modify violent tropical storms. When forecasters predicted that a depression might grow into a hurricane, planes were sent to drop the crystals over the clouds near the centre of the wind system. The rain that was triggered fell through up welling warm air currents, cooled them and possibly prevented the storm clouds from building up to a dangerous extent.

Tree planting

Trees affect the weather in several ways. At the 'micro' levels they can act as windbreaks, preventing valu-

On board a NASA 'laboratory' plane over Antarctica, a scientist studies measurements of ozone and other atmospheric gases.



SMOKE TRAP

Car exhaust fumes and factory smoke tend to rise because they are generally warmer than the surrounding air. The temperature of the air normally falls with increasing height, so the polluting gases tend to rise to a considerable height before they are dispersed. However, unusual weather conditions can sometimes form a 'temperature inversion', in which a layer of warmer air lies above cooler air near the ground. Fumes are then trapped at ground level and are liable to form smog (a mixture of smoke and fog). This is not just unpleasant, but potentially deadly to people with respiratory ailments. Los Angeles is famous for its smogs, which are largely due to its heavy road traffic.



Hutchison Library

is planting trees to increase rainfall and thus promote agriculture.

There is a longer-term reason for planting trees. Like all plants they absorb carbon dioxide; this is one of the major gases involved in the 'greenhouse effect', which may be causing the world to warm up.

The greenhouse effect

The greenhouse effect is the trapping of the Earth's heat by the atmosphere, which keeps the Earth about 33°C hotter than it would otherwise be. The glass of a greenhouse acts similarly – it lets visible light through to warm the interior of the greenhouse, but traps the heat radiation that tries to escape.

Artificial 'weather'
in this dome
provides escape
from English rain at
a holiday village.
Another controlled
environment –
Biosphere II –
exists in the USA
for research
purposes.



Sealand Aerial Photography

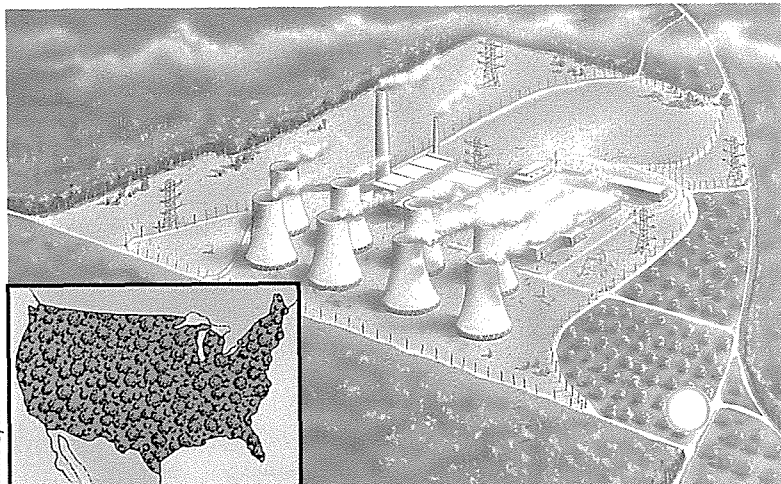
The various gases making up the atmosphere contribute to the greenhouse effect by different amounts. The most important is carbon dioxide, which is released when any fossil fuel (such as oil, wood, gas, coal or charcoal) is burned to provide heat or light, and when trees are burned to clear forests. To counteract all the carbon dioxide produced by burning fossil fuels, it has been calculated that an additional seven million square km of forest would need to be planted.

There are several other important greenhouse gases. Methane is released in natural gas fields and by bacterial action in the ever-growing number of rice paddy fields. Nitrous oxide is given out in car exhausts. Chlorofluorocarbons (CFCs) are used in spray-can propellants and

To absorb CO₂ from a new coal-burning electricity plant in Guatemala, its builders are partly funding the planting of 52 million trees. It would take a forest the size of the USA, excluding Alaska, to absorb world output of CO₂.

Felling rain forests for timber, as here in Zaire, threatens to cause a rise in the global levels of atmospheric CO₂.

Chris Lyon



refrigerator coolants, and for cleaning electrical components.

The extra amounts of these gases put into the atmosphere by human activity may have the effect of raising the mean temperature of the Earth – possibly by 1°C by the year 2025, although scientific opinion is very divided over this.

Such a temperature rise could have devastating effects. The weather might change radically. Deserts could spread further north and south from the equator. The US grain belt might become a dustbowl and the monsoons of the Indian subcontinent and Far East could become more intense.

CFCs probably harm the atmosphere's ozone layer as well. Ozone gas is distributed throughout the atmosphere, but is found in the greatest concentrations 20–30 km

up. The ozone layer screens the Earth from much of the ultraviolet present in sunlight. Whenever the weather is sunny, many people take the opportunity to sunbathe and get a tan. It is ultraviolet light that causes tanning, but it ages the skin, and in excess it causes skin cancer.

The ozone hole

In the mid-1980s, the British Antarctic Survey discovered a 'hole' (actually a reduction in concentration) in the ozone layer over the Antarctic. This is primarily caused by CFCs. Research has shown that ozone levels in the atmosphere are down, worldwide. This is potentially serious since a one per cent fall in ozone level could cause a five per cent rise in skin cancers.

International efforts have been

made to avert this weather threat. In 1987 numerous countries, including the USA, the USSR and Britain, signed the Montreal Protocol on substances that deplete the ozone layer – an agreement to reduce the amount of harmful CFCs released into the atmosphere.

Just amazing!



CHILLING PROSPECT

BURNING FOSSIL FUEL COULD COOL THE EARTH, NOT WARM IT, IF THE DUST PRODUCED WERE TO BLOCK OUT SUNLIGHT. THE TEMPERATURE FALL COULD RESULT IN ICE-SHEETS ALL OVER THE NORTHERN HEMISPHERE, STRETCHING AS FAR SOUTH AS LONDON.

Paul Raymond



SPEEDING AHEAD



Ford

● EASY COMMUTING

● TOMORROW'S CARS

● SUPER-TRAINS

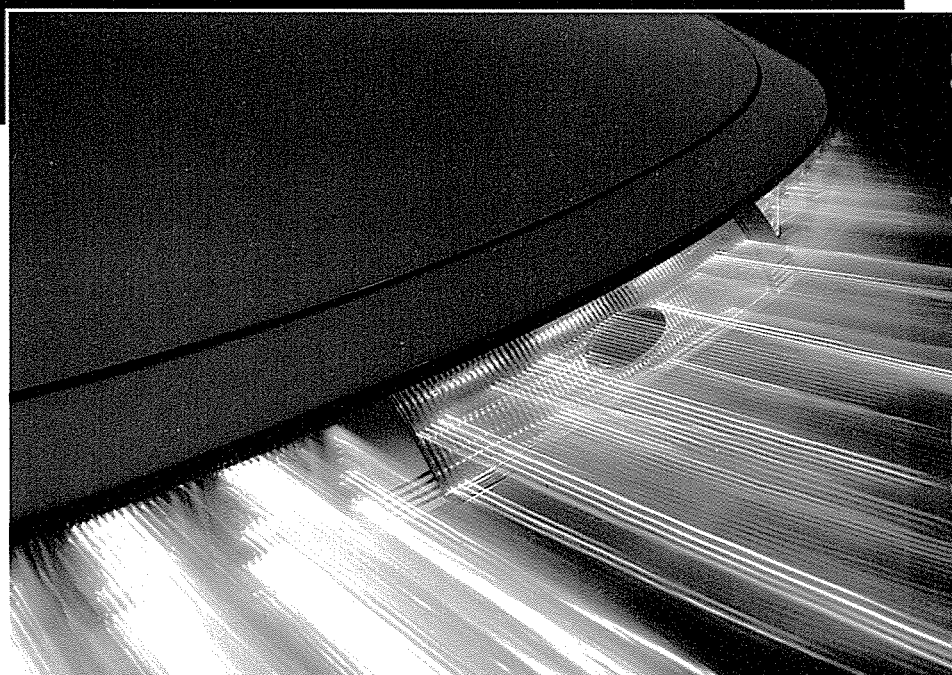
AS ROADS BECOME MORE and more crowded and travelling becomes more of a strain, the major car manufacturers are updating their models with the emphasis on taking the stress out of driving; prototype models of the car of tomorrow are already in existence.

Visually, the most obvious change in the body construction of future cars will be a total lack of seams. Windshields may curve over the driver's head while the rear window will merge with the body, eliminating gaps and ridges that can create turbulence and wind noise.

The major changes, however, will lie under the bonnet, where an integrated electronic system will be used to aid, or replace, many of the present mechanical systems.

Acting as a powerful integrated electronic nervous system and central brain, it will be capable of:

- automatically unlocking doors, starting the car and the radio, moving seat and steering wheel to preprogrammed preferences



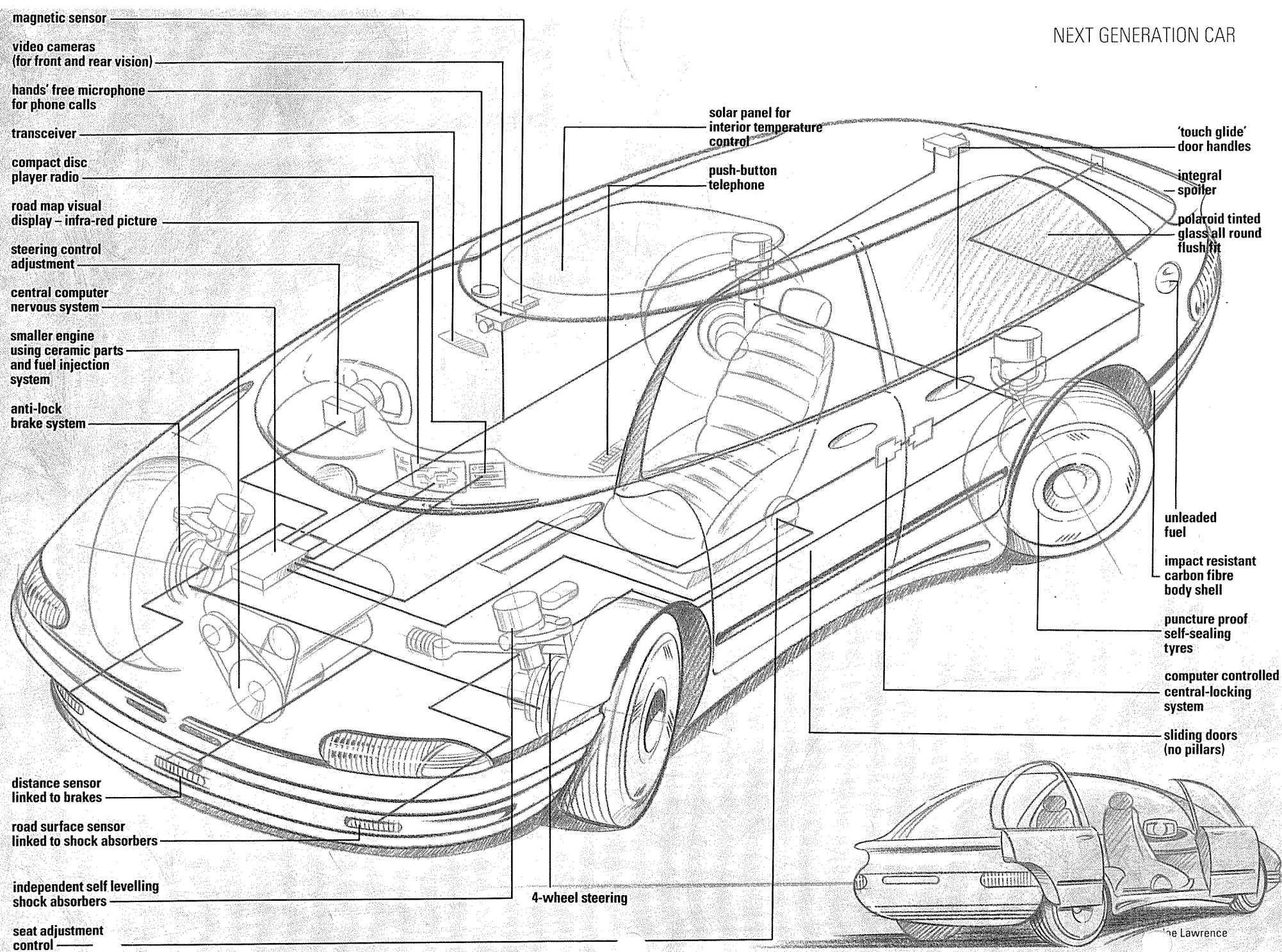
- monitoring the slightest engine malfunction
- measuring the distance between you and the car in front and automatically applying the brakes if the gap narrows dangerously
- responding to potholes or bumps in the road by moving each wheel up and down to compensate for irregularities
- controlling acceleration by sending an electronic signal to the computer to control the throttle.

Safety measures in tomorrow's car will include:

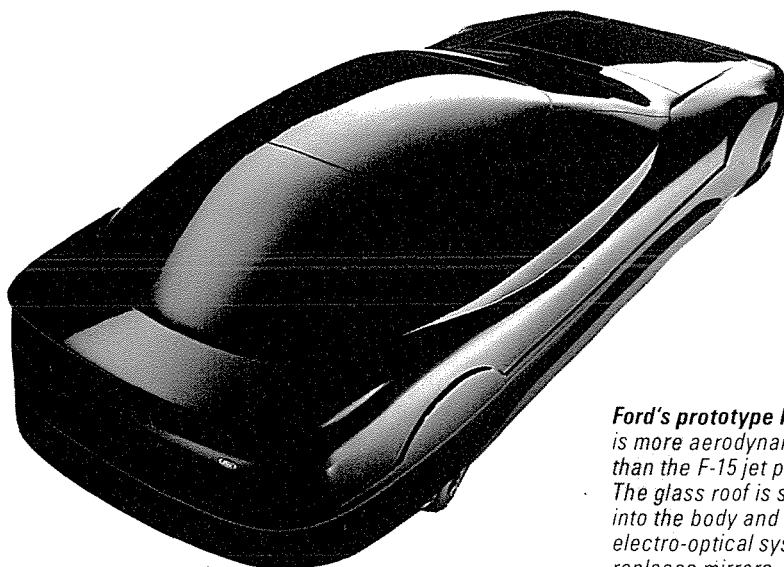
- sensors that will scan blind

***The car of the future** will be lighter, slicker and smaller – indeed, it will be so aerodynamically sleek and efficient, it may even be able to fly. Instead of rolling on tyres, cars might float on a cushion of air, up to 30 cm above the ground. When cars float and friction is no longer a problem, tiny amounts of energy will whisk a vehicle in any direction. When cars have their own power plants to transform sunlight into energy, petrol engines could become obsolete.*





Ford



Ford's prototype Probe V is more aerodynamic than the F-15 jet plane. The glass roof is sculpted into the body and an electro-optical system replaces mirrors.

- the fewest possible tunnels – or else airtight locomotives and carriages, so that passengers will not be disturbed by sudden sharp changes in air pressure
- advanced signalling, to give drivers more warning of when to slow down
- stronger, heavier rails.

Tracks and trenches

All the super-trains running today and those planned for tomorrow are powered by electricity drawn from overhead lines. The French high-speed trains, called TGVs (*Trains à Grand Vitesse*) have two power cars, one at each end.

The TGVs require their own specially built straight track. The track

spots for possible dangers

- a dashboard display that will show an infra-red picture of the road ahead to enhance vision at night or in foggy conditions
- increased use of antilock brakes and electronic traction control.

Modern engines

Future models will still be powered by internal-combustion engines, but in a more sophisticated version than anything in use today. The hottest engine parts will be made of ceramics or new metal alloys now being tested.

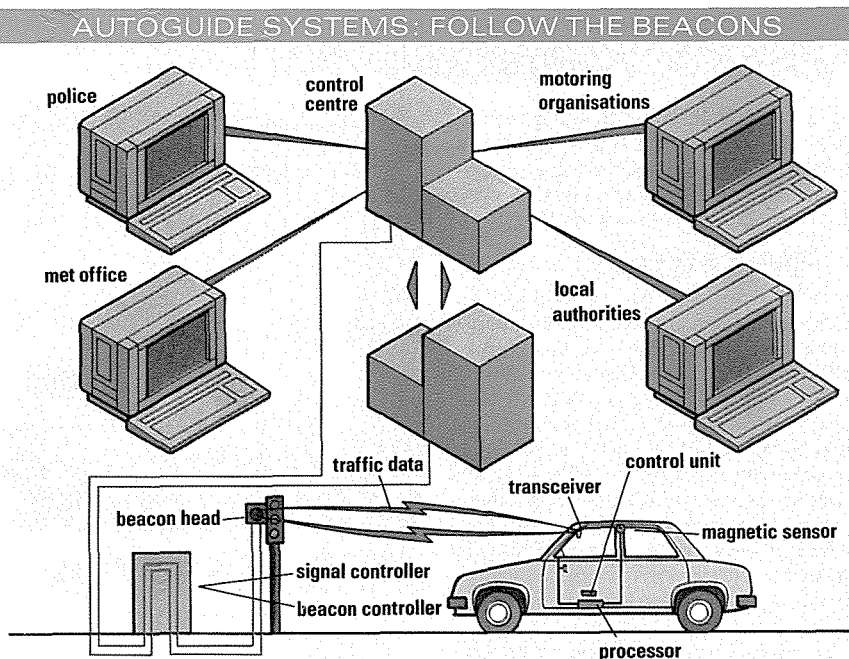
Most cars will use computer control fuel injection systems instead of the simple carburettor, which blends air and vaporized petrol before they enter the engine cylinder.

New engines will also be wired up with sensors that track everything from the amount of oxygen in the exhaust to vibrations in each cylinder.

Tomorrow's trains

Only 20 years ago, it was being claimed that long-distance train services would shrink to insignificance in the face of competition from road and air transport. But today, a new generation of super-railways is being built in Europe and Japan that will carry passengers at 300 km/h.

In 1955, the first world rail speed record of more than 300 km/h was set by a specially modified French train. But setting records is very far from establishing regular services at such speeds. That requires, quite



Mark Franklin

Beacons situated at strategic points relay information to cars fitted with two visual display units plus an infra-red receiver and transmitter that are both linked to a central computer. The driver keys in the map reference for his destination. As the car passes each

beacon, detailed directions appear on the screen and a synthesized voice issues instructions. Each beacon recognizes where the car wants to go and directs it to the next relevant beacon for further instructions. The system is interactive.

apart from powerful locomotives:

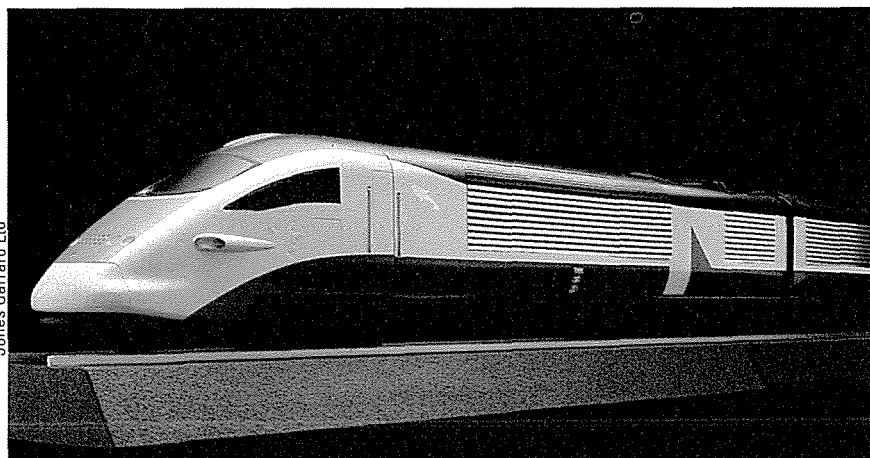
- the straightest possible track and banked curves, or difficult and costly adaptations of the trains to enable them to corner fast – such as tilting carriages.

climbs hills rather than going round them – the trains are powerful enough to be able to cope with gradients of up to 3.5 per cent. Onboard sensors detect a slope and adjust the power accordingly.

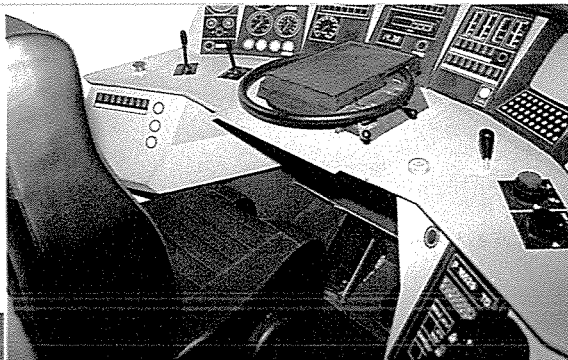
There were no tunnels on the first TGV routes in south-eastern France, because of worries about the

This super train, destined to carry passengers from a terminal in London to Paris via the Channel Tunnel will reach speeds of 160 km/h through south-east England. At the tunnel terminal it will plunge underground and maintain this speed during its 35 minute crossing.

Jones Garrard Ltd



Electronic signals displayed inside the cab of the TGV, telling the driver what his speed should be, come from a single control centre at Lyon. There is also a radio telephone link.



French Railways

TGV-Atlantique in western France. Trains on this network were the first able to carry passengers at up to 300km/h. Speeds of up to 270 km/h are reached in some tunnels.

In Germany, a new type of electric train called ICE (Inter-City Express) is capable of 300 km/h. But for safety, they operate only at 270km/h, and only on certain stretches of track. Adjacent tracks are more widely spaced than normal, to give the trains more room to pass each other in tunnels.

In Australia a VFT (Very Fast Train) is proposed, with a maximum speed of 350 km/h. The travel time from Sydney to Melbourne, over 850 km, would be cut to just three hours.

The imminent opening of the Channel Tunnel has prompted British plans too. Proposed trains

The French TGV came into operation in 1981 and uses its own specially built track that no other trains can operate on. The line was built with as few curves as possible so constant speeds can be maintained. The train is powered by electricity – a pantograph receives an electric current from overhead wires.



French Railways

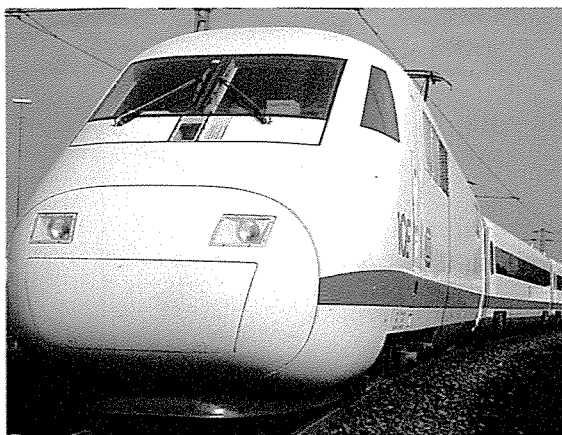
effects of a train slamming into a mass of air inside the tunnel that could not escape fast enough. So in some places the track had to pass through huge trenches instead.

The great race

In 1965, the famous Japanese 'bullet trains' were first to provide regular services at average speeds above 160km/h, with a maximum of 210 km/h in some places. Today, they touch 270km/h on some routes. A new type called the Series 300 was introduced in March 1992. It has a smaller cross-section to cut air resistance, and numerous other technical improvements, including lightweight aluminium construction. These boost its maximum speed to the 300km/h signified by its name.

In 1989, France opened the first section of a new rail network called

The 'bullet train' of Japan – the first high-speed train to provide regular services – has been updated so that it can reach a top speed of 300km/h.



Deutsche Bundesbahn

The German ICE is capable of speeds up to 300 km/h – but this is restricted, in the interests of safety, to a top speed of 270 km/h. Germany is also concentrating on mag-lev trains, which run on a magnetic cushion, and intends to build a high-speed mag-lev line between the towns of Hamburg and Hanover.

BREAKING RECORDS

On 28 March 1955, a French train hurtled along a stretch of track at more than 300 km/h, breaking the world speed record. But one of its pantographs – a metal framework taking power from overhead power lines – melted in the enormous frictional heat. Next day another train recorded 331 km/h, and lost a pantograph at the same spot.

would consist of 14 cars. At each end there would be a Super-Electra locomotive, developed from British Rail's new Electras. Each would deliver 5,000 kW of power and would be able to work from any of the very varied types of electrical supply used in France, Belgium, the Netherlands and Germany.

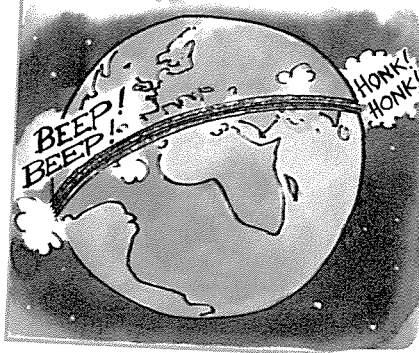


Tony Stone Photo Library, London

Just amazing!

SUPER JAM

IF ALL THE CARS IN THE WORLD JOINED THE SAME TRAFFIC JAM, IT WOULD CIRCLE THE EARTH 34 TIMES.



Paul Raymond



ELECTRONIC BRAIN

- MEMORY CHIPS
- TALKING COMPUTERS
- EXPERT SYSTEMS

AN ELECTRONIC REPLICA OF the human brain may be built sometime next century. It may even become possible to transfer everything stored in a human brain to an electronic one.

This would mean that, centuries after the body had perished, a person could continue thinking and, with suitable equipment connected, doing useful work.

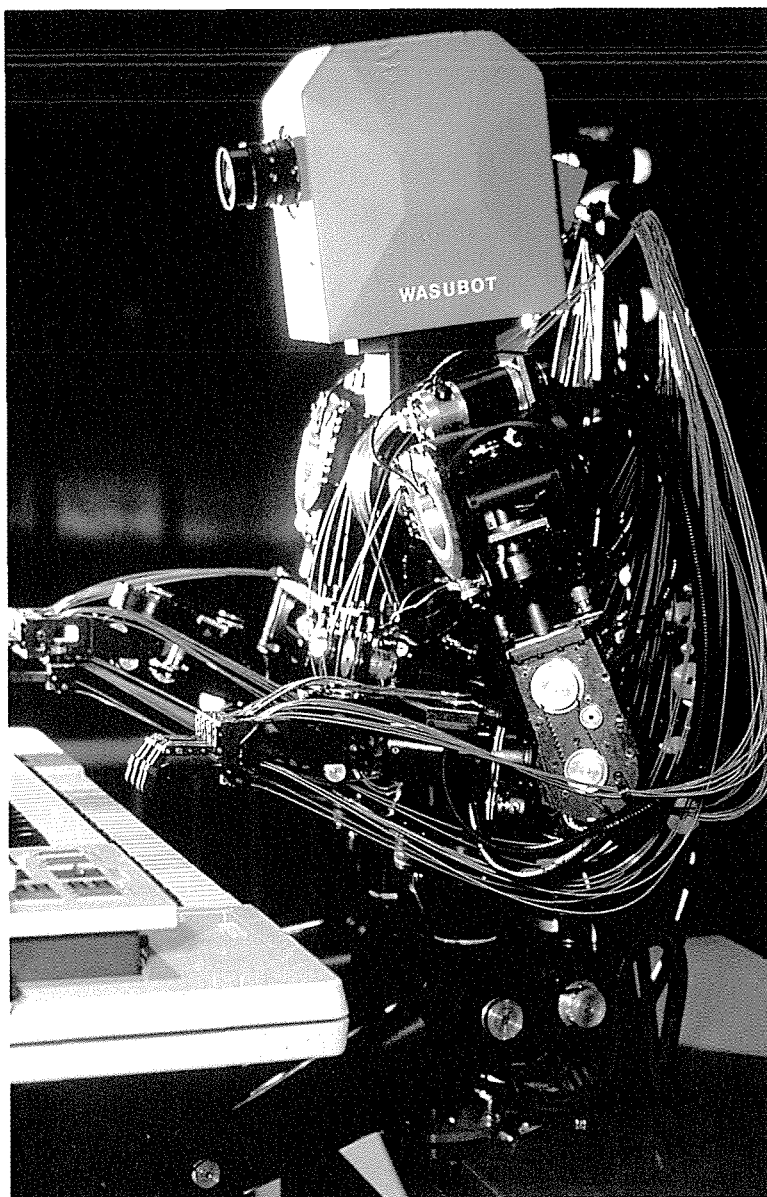
Just as the human brain communicates with the outside world through the senses for input, and through speech and movement for output, so an electronic brain — a computer — must be linked to input and output devices if it is to be of use.

Most computers are already linked to standard input and output devices — a keyboard and a screen — but the computer is an ideal 'brain' for a wide range of other electronic and mechanical devices. These provide the computer with 'senses' to receive information from the outside world and with the means to carry out some action in response to the information received.

Programming

Before it can do anything useful, a set of instructions called a program has to be fed into the computer. This tells the computer everything it needs to know in order to carry out a particular task.

Most computer programs are stored as a series of magnetic pulses on an iron-oxide-coated tape or disk. A tape or disk unit connected to the computer converts the magnetic pulses into electrical pulses. These are stored in the computer in tiny integrated circuits called memory chips. With a program thus installed, the computer



Charlie Cole/Colorific

A humanoid robot plays music on a keyboard — a task involving high-precision computer control and engineering. Something the modern robot is well equipped with.

can accept signals from an input device and respond to them by operating an output device. This whole process is controlled by another kind of chip called a microprocessor.

If suitable programs and appropriate input and output devices are available, the computer can carry out a wide range of tasks. With a keyboard and printer, the computer becomes a word processor. With an amplifier and loudspeaker connected, it can act as a music synthesizer. Linked to a mobile vacuum cleaner, you could have a robot that cleans the carpet.

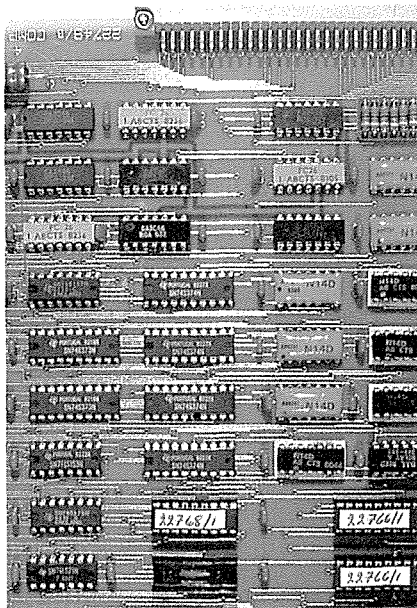
In all of these applications,



David Parker/SPL

Memory chips (enlarged) on a silicon crystal before being encapsulated in plastic.

Circuit board of a computer with encapsulated chips (integrated circuits) soldered in position.



J A Wall/SPL

the computer can be said to act as an electronic brain. In some ways, the computer can easily outperform the human brain. For example, it can work out long mathematical problems rapidly – and with a guarantee of accuracy.

Unlike a person, a computer does not normally forget information that it has been given, no matter how much of it there is. The computer can also work on problems non-stop for weeks, months, or even years. However, some tasks that are extremely easy for people to perform prove much more difficult for the computer.

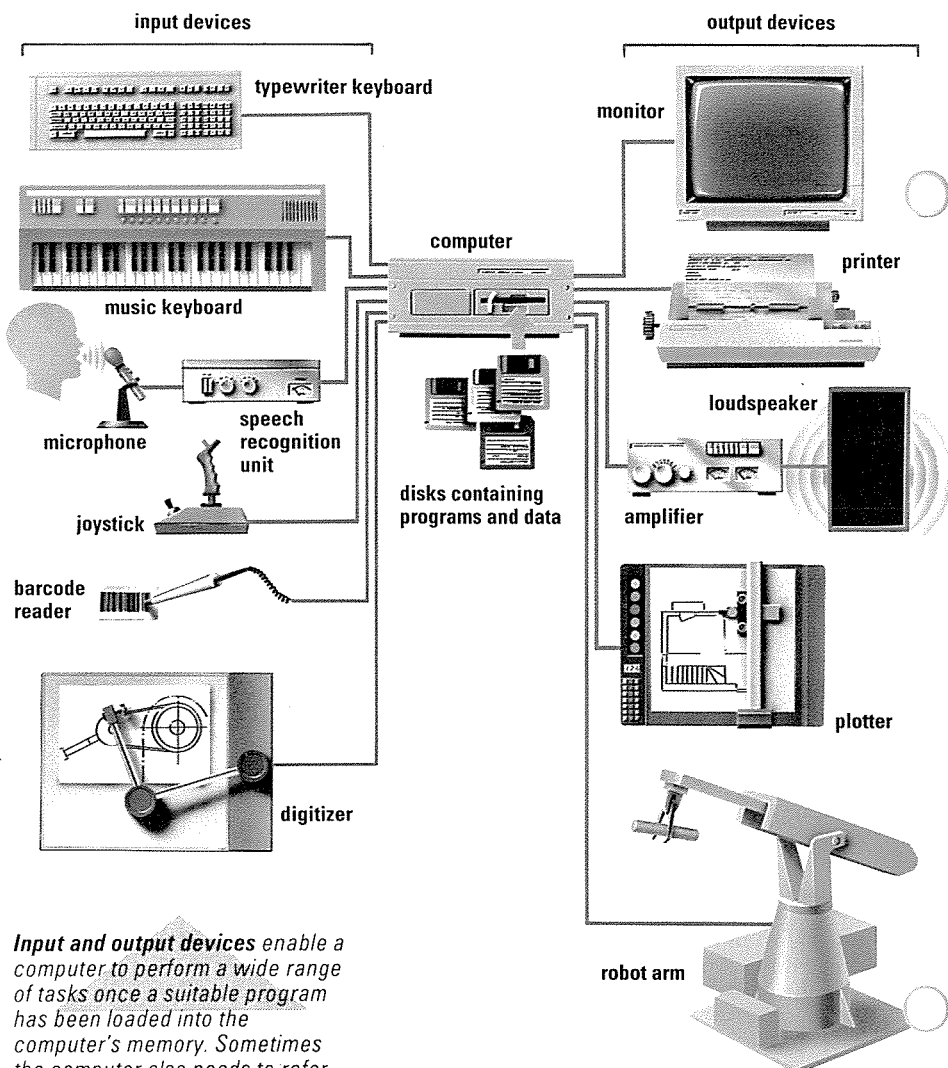
Pattern matching

One such task is that of recognizing objects. In a manufacturing process, for example, a computer may have to recognize the component parts of an item and make a robot sort them into piles. Recognizing a shape is more difficult than might be expected. A TV camera pointed at the object will produce an image that the computer can compare with patterns stored in its memory. When it finds a matching pattern, the computer 'knows' what object the camera is looking at and can make the robot pick it up and place it in the right pile.

Janos Marffy

However, even a flat, oblong-shaped part will not be recognized until its image is rotated to match the one stored in the computer memory. This is not difficult to do, but it does slow down the recognition process.

Three-dimensional objects take



Input and output devices enable a computer to perform a wide range of tasks once a suitable program has been loaded into the computer's memory. Sometimes the computer also needs to refer to a data (information) disk.

The \$20 million Cray 2 supercomputer, running 250 times as fast as a home computer, is still not fast enough to compete with the chameleon when it comes to catching a fly. By the time the computer had identified a TV image of the fly and extended a robot arm to grab it, the fly would probably have moved off or flown away altogether.

Stephen Dalton/NHPA

even longer for the computer to recognize if it is possible for them to appear before the camera any way up and at any angle. Also, the average time taken to identify a part will depend on how many patterns the computer has to compare with the TV image.

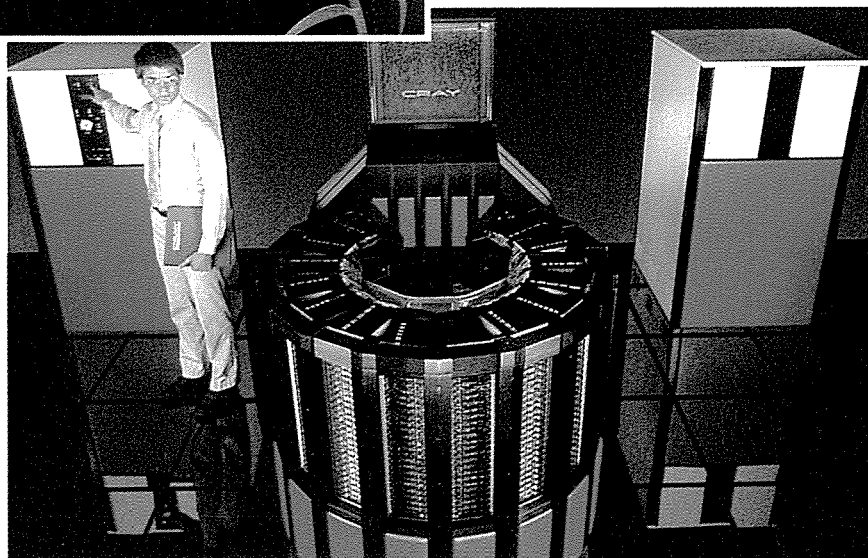
By comparison, our brain performs amazingly well. In most cases, we have only to glance at an object to recognize it in a tiny fraction of a second. It could be any one of thousands of objects, at any angle and at any reasonable distance.

Even frogs, which have very simple brains, are extremely quick in recognizing the flies that they feed on, regardless of the angle from which they see them. Many computer scientists are irritated to find that these simple creatures can beat their multi-million pound supercomputers at such tasks. However, this fact may eventually lead someone to discover more effective pattern recognition techniques for use in computers.

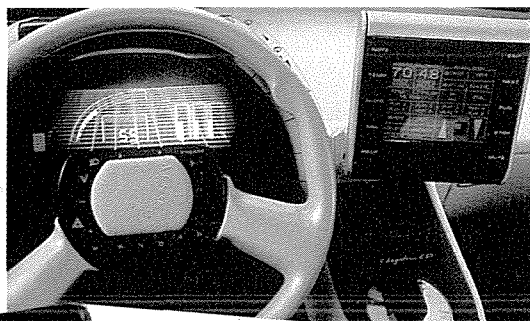
Speech recognition

People often control their computers by using a keyboard. For example, when using a games program,

Paul Shambroom/Cray Research Inc



In-car computers use signals from the engine and accessories to display data on a screen. This shows journey time, fuel consumption and even what can be heard on the compact disc player.



George Hayling/SPL

great deal of computer power if the system had to respond to the words regardless of the accent in which they were spoken.

For this reason, many speech recognition systems require the user to teach the computer what the words will sound like. Each word to be recognized has to be spoken several times into a microphone. The computer stores each speech pattern in its memory so that, when a command is spoken, the computer can compare this speech pattern with those stored in its memory. If the computer finds that the command closely matches that of one of the stored patterns, then it will respond to the command and send out the appropriate control signals to the machinery.

Computers able to recognize words spoken in a variety of accents need to be much more powerful. Such machines are used by some companies to connect telephone callers to the correct extension whether they ask for it by number or by the name of the person or department that they want.

Syntax

For more elaborate enquiries, callers would have to ask to talk to a human operator, for a computer simply could not cope. Even if it could recognize a vast range of words, spoken in any accent, there is an even greater problem to solve – syntax. This refers to the way that words are arranged in order to make sense.

Some words with quite different meanings sound the same when spoken. So it is only by considering the structure of the phrases, clauses or sentences containing

pressing a single key may fire a gun or move an object across the computer screen. An alternative method is to use spoken commands to communicate with the computer. A microphone picks up the sounds and converts them into electrical signals. These are fed into a speech recognition unit, which is connected to the computer. The unit recognizes the spoken commands and controls the computer accordingly.

This is sometimes done in situa-

Car shapes and body finishes can be created on a computer screen with the aid of graphics software. Instead of spraying real cars, various colour schemes can be tried out quickly on the screen.

tions where it is inconvenient for a person to have to type commands in on the computer keyboard. For example, in a factory, a computer might control equipment for lifting heavy objects and moving them to another position. The person controlling the operation may need their hands free for other tasks, or may not be able to stay near the keyboard.

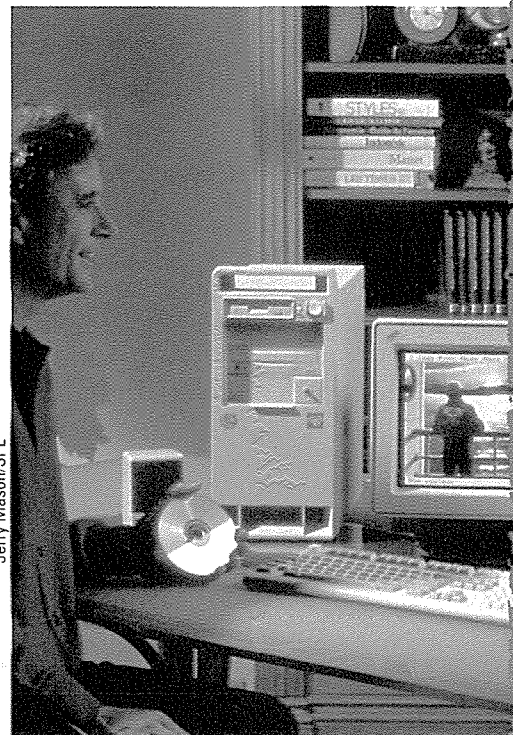
Teaching the computer

In such cases, it is much more convenient to program the computer to understand simple spoken commands, such as 'right', 'left', 'up', 'down', 'forward' and 'back'. On recognizing such a command, the computer sends out signals to control electric motors in the machinery, thus making it carry out the required action.

Even a simple speech recognition task such as this would require a

Composing music is simple when a suitable program is loaded into a home computer. The pitch, quality and duration of the notes are controlled from the computer keyboard.

Tony Stone Photo Library, London



Jerry Mason/SPL

Just amazing!

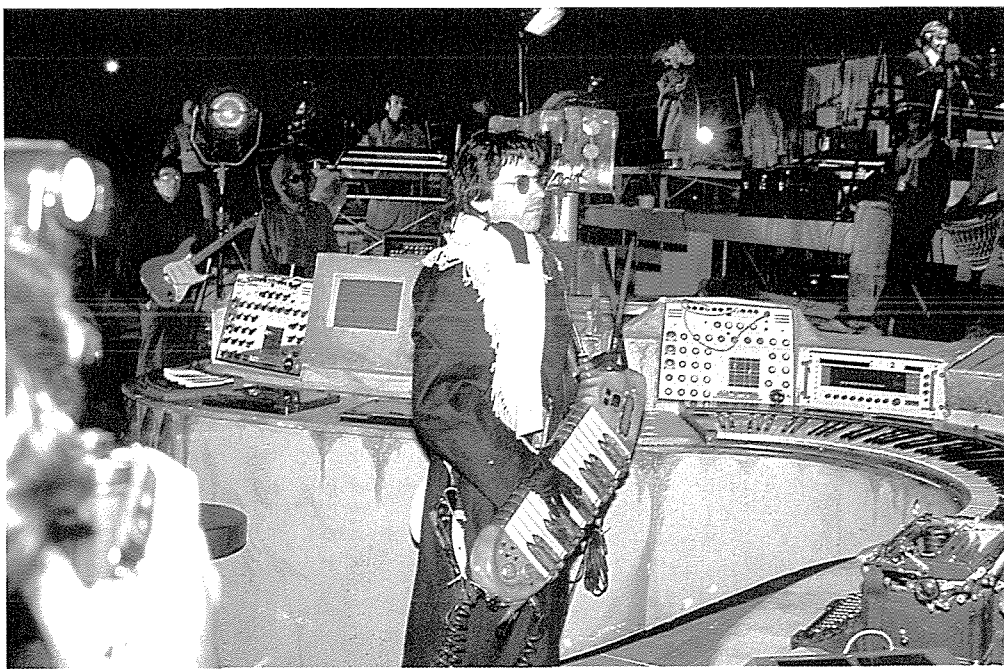
PHONEY OPERATORS

SOME COMPANIES HAVE COMPUTERS THAT ANSWER THE TELEPHONE. ASK WHO YOU WANT TO SPEAK TO AND CONNECT YOU TO THE RIGHT EXTENSION. THEY WILL EVEN TAKE A MESSAGE IF THE PERSON YOU WANT IS NOT AVAILABLE.



Paul Raymond





Music synthesizers and sequencers now play a major role in most pop music performances. The synthesizer is a kind of computer designed for generating sounds electronically. The sequencer memorizes sequences of notes and plays them back.

Speak and Spell is a computer that teaches children how to spell. The computer speaks a word and the child tries to spell it out on the keyboard. The computer then tells the child whether the spelling is right or wrong.

them that we – or computers – can decide what such words mean. Some progress has been made in getting computers to solve this problem, but it will be some time before they will match the human brain when it comes to recognizing speech.

Computerized sounds

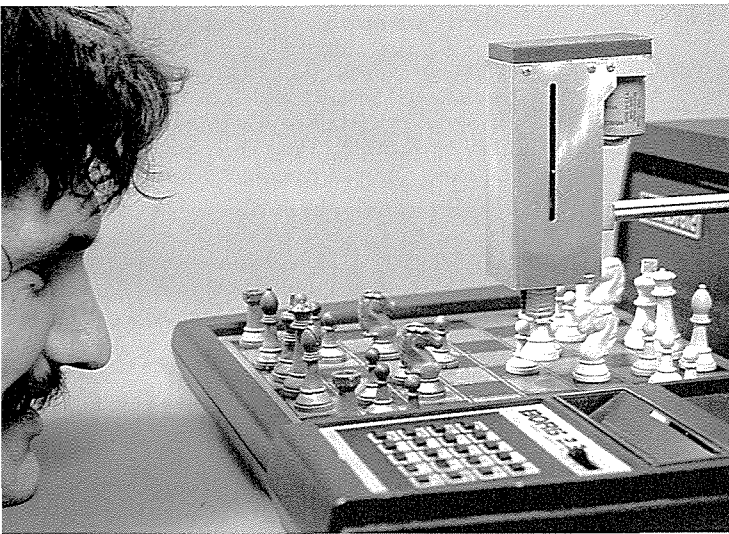
Once a computer has received a spoken command or request, it can easily be made to talk back. It may say that it does not understand what you have said and ask you to repeat the words. Or it may tell you that your message is understood

Computers can also produce musical sounds. Programs are available to turn home computers into simple music synthesizers so that you can compose, store and replay tunes on them. Some systems will even provide you with a printout of the music you have composed.

Like the brain, a computer receives and stores information, makes decisions based on logic and produces answers to problems. In any task it does, a computer seems to demonstrate that it is a machine with artificial intelligence. Some computers seem remarkably intelligent when carrying out a complex task.



Chess-playing computers usually display the game on a screen, but this one uses a robot arm to move real chess pieces.



Dan McCoy/Black Star/Colorific

and that it is taking appropriate action – connecting your phone call, controlling a robot or doing whatever else you asked.

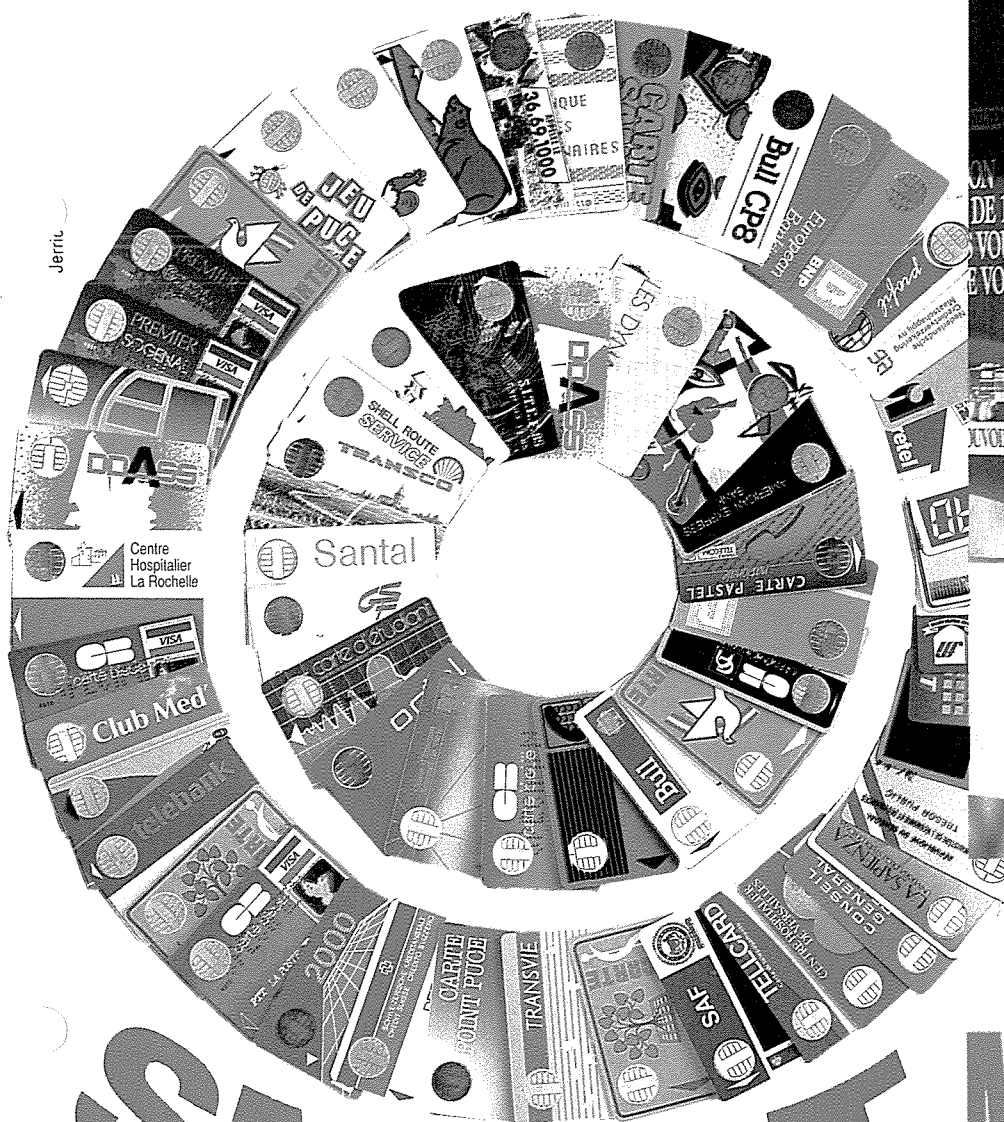
Computers form speech sounds using devices called speech synthesizers. These use memory chips to store sounds as electrical signals. Some units can build up any complex word from several separate sounds. Other types store whole words or sentences and usually sound much more realistic. However, they may have a much more limited vocabulary.

Diagnosis is one area in which computerized expert systems are playing an important role. Information from an x-ray scan is analysed by the computer, which then indicates the nature of the patient's illness.



ZEFA





Customers with a plastic card can draw cash from their bank machine at any time of day or night in many countries.

SMART

MONEY

-  CASH DISPENSERS
-  SECRET NUMBERS
-  MICROCHIP CONTROL

MANY PEOPLE WILL SOON carry a tiny computer with them wherever they go. This will be embedded in a plastic 'smart card', which will replace the various plastic cards that people now use to get money from their bank accounts or to pay for goods and services.

These cards act as charge cards, credit cards and cash cards. Plastic cards are issued by various organizations, such as banks, credit card companies and large stores. But, no matter who issues them, they are all the same size and, except for the smart cards, have the same basic features.

The standard credit card or cash card is 86 mm wide, 54 mm high and less than 1 mm thick, with the customer's name and account num-

ber embossed on the front. On the back, there is a space where the customer has to write his or her signature, plus a dark, narrow stripe of magnetic material.

This stripe (similar to the surface of recording tape) carries recorded data, such as the customer's account number, that can be read by machine. This stripe has three tracks which, together, can hold up to 226 letters and numbers.

Charge and credit cards

Charge cards, such as those issued by Diners Club and American Express (Amex), and credit cards, such as Access and Visa, were the first types of plastic card to be introduced.

When you buy something with a charge or credit card, the card company pays the shop for what you have bought, then sends you a bill. With a charge card you have to pay the full amount straight away.

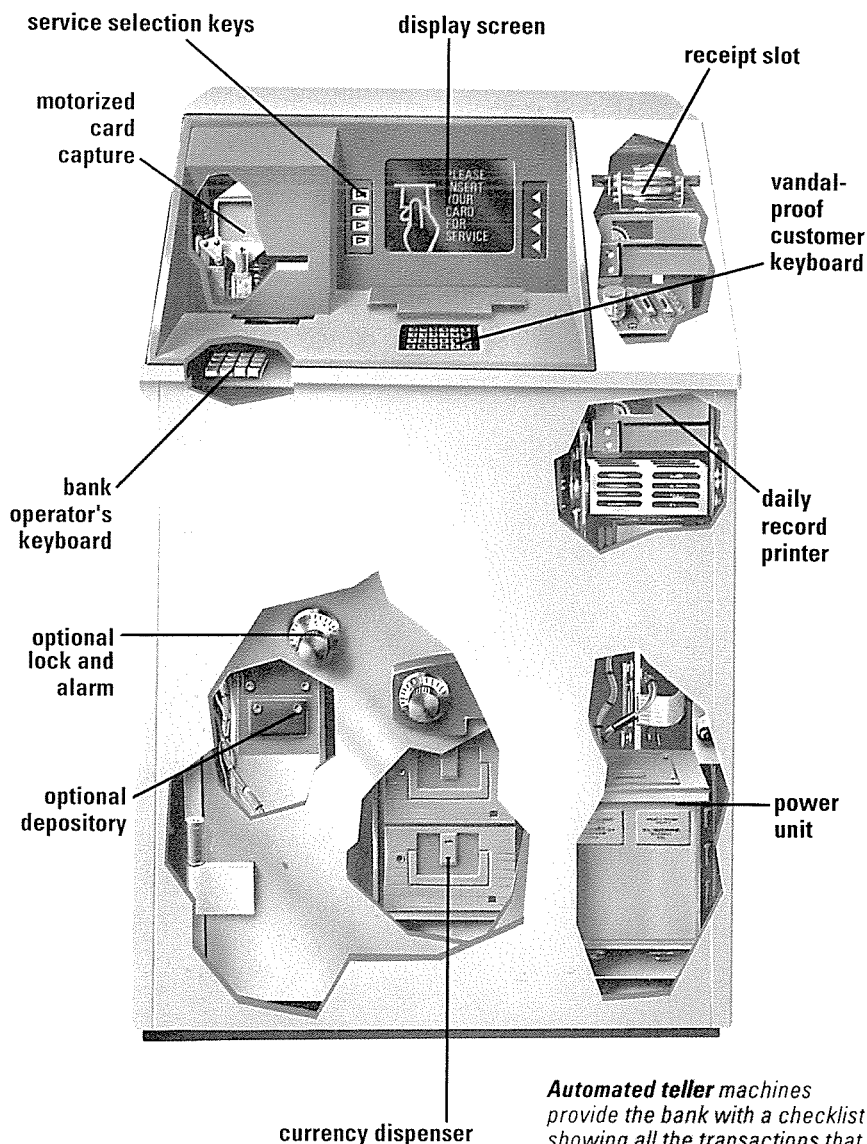
With a credit card, however, you can pay in monthly instalments. The credit card company tells you what your minimum monthly payment should be and charges you interest on the unpaid amount.

Cash cards

Most banks and building societies have networks of card-operated cash dispensing machines from which their customers can get money at any time, day or night. These machines, called automated teller machines (ATMs) are linked by private telephone lines to the central computers of the banks or other organizations that operate them.

To use a cash card, you feed it into a slot in the ATM and then key in your personal identification number (PIN) on the machine's keyboard. The PIN is a 4-digit number — a sort of password that the bank gives you when it issues you with your card.



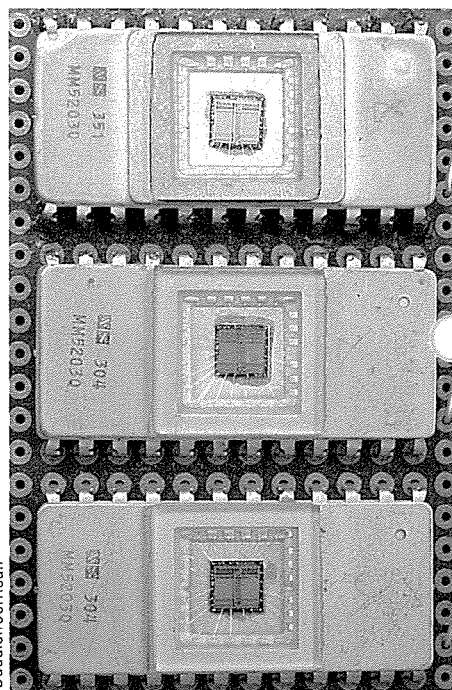


Automated teller machines provide the bank with a checklist showing all the transactions that have taken place in the last 24 hours.

The computer checks that the PIN number you key in is the correct one for your account number, which the ATM has read from the magnetic stripe on the back of the card. You will not be able to use the machine unless it is. This is to stop unauthorized use of your card. You are supposed to keep your PIN number secret so that no-one else can use your card if it gets lost or stolen.

If you make a mistake when keying in your PIN number, the machine lets you try again. But if you get it wrong three times, it keeps your card and you have to ask the bank for a new one. The banks assume that, if someone gets the number wrong three times, they are probably an unauthorized user trying to obtain money by using someone else's card.

When you have keyed in the right PIN number, the machine usually gives you a choice of services,



Integrated circuits (silicon chips) provide the computing power required in today's money dispensing machines.

which are shown on its display screen. Besides giving you cash, the machine can let you check your bank balance, order a new cheque book or ask for details of your account to be sent to you. You choose the service you want by pressing a button next to the display screen.

To get cash, you select the amount you want on a set of buttons. The machine checks with the computer to see if you have sufficient funds in your account, and whether or not you have exceeded any daily or weekly limit set by the bank on how much can be withdrawn using the card. If all is well, the machine counts out the

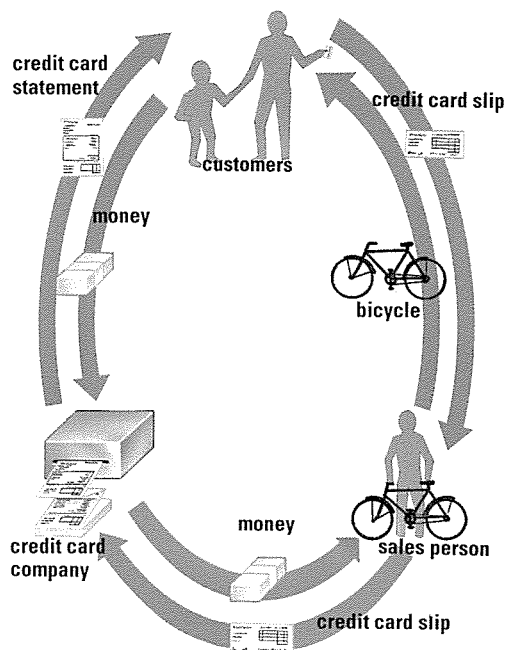
Daudier/Jerrican

Mark Franklin

CREDIT PURCHASES – BUY NOW, PAY LATER

When you purchase an item by credit card, the card is usually placed in a small machine that transfers embossed details from the card on to slips of paper. A description of the item and its cost are written on the slips, which the customer then signs.

The salesperson checks that the signature on the slips matches the one on the card to make sure that the person with the card is entitled to use it. The store and the customer each keep a sales slip. The store sends its used slips to the credit card company, which then pays the store the necessary amount, less a small charge for the service. Once a month, a statement is sent to a customer showing what is owed. This can be paid all at once, or in instalments. Interest is charged on any unpaid amount.



TELEPHONE CARDS

One of the simplest substitutes for cash is the Phonecard, which can be used in many public telephones. Phonecards of various values can be purchased in Post Offices, newsagents and other shops in the UK. Their value is recorded on a magnetic coating on the back. Before making a call, the card is inserted in the telephone equipment. This automatically reads the value of the card and deducts from it the cost of the call. You can use the card for calls until the amount you paid for it has been used up.

An alternative to the Phonecard is the telephone credit card. The telephone company's computer records your card number and the cost of each call that you make. You are sent a bill every three months.

It is also possible to use some credit cards and charge cards to get cash from bank ATMs, using a PIN number issued to you by the card company.

When you do this, the bank's computer tells the credit card company how much money you have had, so that it can be paid back to the bank and charged to your credit card account.

Eftpos

The latest step towards the 'cashless society' is the introduction of Eftpos — Electronic Funds Transfer at the Point Of Sale. This is a huge

Money is transferred from your bank account to that of the store after your electronic funds transfer card has been checked via a terminal on the counter.

Contactless smart cards have a built-in loop aerial for picking up power from a read/write unit and exchanging data with it — all by means of radio waves.

loop aerial

interface chip

GEC Card Technology
West Hanningfield Rd.,
Great Baddow, Chelmsford,
Essex, England CM2 8HN.
Tel. 0245 72027. Telex: 395016 GECRES G.

nology

Hanningfield Rd.,
Baddow, Chelmsford,
Essex, England CM2 8HN.
Tel. 0245 72027. Telex: 395016 GECRES G.

microcomputer
with memory

Smart cards with built-in microprocessors, are manufactured in sheets of 20 and later cut to size.

computer network linking the computer systems of banks and credit card companies with each other and with terminals installed in shops and other places where goods or services are sold.

With the Eftpos system, you can buy things using either a specially-issued card called a debit card, or your existing cash card, credit card or cheque guarantee card. The shop assistant enters the details of your purchases on the Eftpos terminal the same way as on an ordinary till. Then your card is passed ('wiped') through a slot on the terminal, and you enter your PIN number on a small keyboard.

The terminal calls up your bank or credit card company computer to check that it is all right for the sale to go ahead. If it is, the cost is automatically deducted from your bank account, or charged to your credit card account, and paid into the shop's bank account.



Pitchal/Jerrican

notes and delivers them through a slot. The central computer automatically deducts the amount from your bank account.

The machine may then ask you if you want to use any of its other services. If you do, it tells the central computer what you want and the computer arranges it for you. If you do not require any other services from the machine, it returns your card.

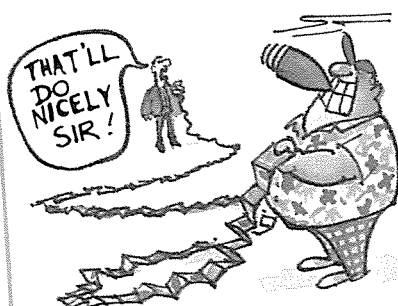
Flexibility

Many banks that operate ATMs have arrangements with each other so that you can use a cash card issued by one bank in the ATMs of another. Eventually, anyone with a cash card will be able to use it in any ATM. This is already the case in Italy and, by the end of the 1990s, all the ATM systems in Europe will be interlinked.

Just amazing!

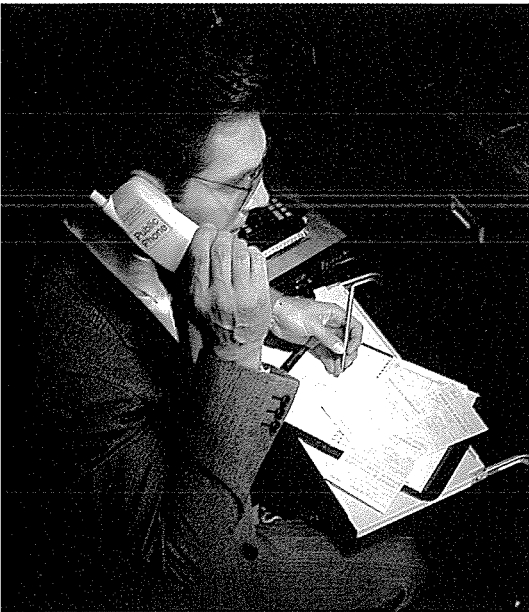
WALLET WALLY

THE WORLD'S BIGGEST WALLET, WEIGHING NEARLY 16 KG AND OPENING TO OVER 76 METRES, WAS MADE FOR WALTER CAVANAGH OF CALIFORNIA, TO HOLD HIS 1,196 CREDIT CARDS.



Paul Raymond





GTE Airfone Incorporated

cards have a set of contacts along one edge and can be plugged into cash dispensers, payphones or other terminals. However, the contacts sometimes get damaged or dirty, preventing correct operation, so contactless cards have been developed more recently.

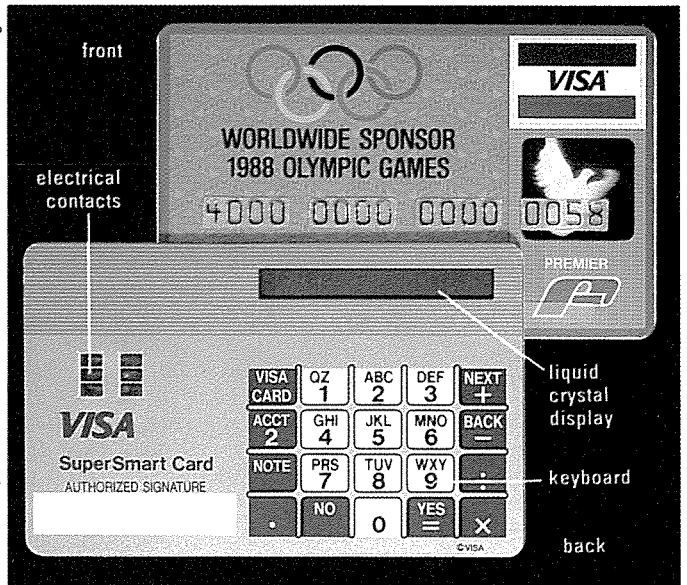
The contactless card, invented in England by GEC, contains loops of wire that act like a radio aerial. In use, the card is placed on top of a

like a debit or credit card to buy things. But it can also be used like cash. Using a special bank terminal, you can load the card's memory with 'money' from your bank account and use it to buy small items, such as sweets or magazines. A read/write unit in the shop will deduct the cost of what you buy from the money stored in the card's memory and store the new balance on the card.

Telephoning from an aircraft is now possible on some routes. Payment is made by inserting a credit card in a slot, rather than coins which would be inconvenient on international flights with passengers holding various currencies.

Visa International-EMEA Region

Similar to an ordinary credit card from the front, the back of this smart card has electrical contacts, a tiny display screen and even a keyboard.



The 'smart' card is a new type of card that will eventually replace all our existing ones. The smart card is exactly the same size as a credit card, but has a microprocessor and memory circuits built into it. This enables the card to carry far more data than can be held on the magnetic stripes of ordinary cards.

Multi-purpose

A single smart card can, therefore, be used for many purposes — as a credit card, a cash card or a telephone payment card. It could even be used as an electronic identity card, club membership card or passport.

The first smart cards to be developed are already widely used in France and other countries. These

read/write unit, a flat plate on the cash dispenser or other terminal. Radio waves generated by this unit are picked up by the loops in the card and are used to provide the electricity to power the card's microprocessor and memory. The transfer of data to and from the card is also by radio.

The smart card can be used just

At the moment, smart cards are used with PIN numbers to guard against fraud. But alternative security systems are being developed and, in years to come, the card read/write unit may check your identity by examining your fingerprints or, even more simply, by checking the pattern of blood vessels in your fingertips.

INTO THE FUTURE

ON THE CARDS



Joe Lawrence

▲ Besides taking care of your financial transactions, a smart card may act as an identity card, containing records of your fingerprints (and any convictions).

▲ The card would also act as a passport, with any necessary visas added before departure, and dates of entry and exit added by border officials.

▲ In case of accident, doctors could use your smart card to check your medical record. This would include details of any treatment required for existing problems.



MICRO IMAGES

Mike Goldwater/Network Photographers



- POCKET LIBRARIES
- ATOMIC WRITING
- OPTICAL ID

STORING INFORMATION AS images is as old as human communication itself. Today, these images are stored on the printed page and microfilm, and in digital form in computer memories, on magnetic media, optical cards and discs.

In the future, ever larger amounts of information will be stored in ever smaller spaces — perhaps even on atoms themselves.

Storing information using light is being done by British Telecom and a London hospital. They are using a

Business Imaging Systems/Kodak Ltd



small plastic card, coated on one side with shiny metal, to store patients' medical records. A complete set of records can be stored this way — the card holds the equivalent of up to 800 sides of standard A4 paper covered with text — and the patient can carry their medical ID card around with them.

The information is digitized and burnt into the surface of the card by a small laser in 2,500 rows of small holes. To read the card, another (less powerful) laser sweeps the surface and the variations in the light reflected — caused by the holes — is picked up by a sensor. Both the

Complete medical records can be stored optically on a 'clever' card that patients can carry with them in their wallet.

Vast amounts of information can be stored as digital images on optical discs. The whole of the new Oxford English Dictionary is now contained on just one disc (inset above).

laser recorder and reader are housed in a drive that can be connected to a personal computer.

The information on the card cannot be erased — only added to. There are 2,600 kilobytes available, about three and a half times the data capacity of a personal computer's double density floppy disc.

In future, cards carrying large amounts of data could have many applications. They could carry information about banking, health, identity and could be slipped into write/read slots in banks, at the



Telefocus



Just amazing!

PINHEAD PRAYER

THE LORD'S PRAYER FROM THE CHRISTIAN RELIGION HAS ACTUALLY BEEN ENGRAVED BY HAND ON THE HEAD OF A PIN - AN AREA OF JUST ONE SQUARE MILLIMETRE



Paul Raymond

doctors' surgery and at other places where you need to make transactions or to have information available on the spot.

They have some competition, however, from the so-called 'smart' cards that have tiny computer memory chips incorporated into them. These can be read and updated. They are also more flexible because, under certain conditions, information can be erased.

Optical discs

Compact discs have been around for a number of years. But the disadvantage of the standard optical CD in computer use is that no new information can be recorded on it once it has been manufactured. However, new optical discs for

computers can record information. They are known as WORM discs. WORM stands for Write Once Read Many times.

A powerful laser burns pits in these discs. These pits are then read by a less powerful laser and a detector. IBM sell a 13 cm WORM optical disc which, with the appropriate optical disc drive, can be used with a personal computer. It has a 200 megabyte capacity - about 5 times the capacity of a typical hard disc on a desktop computer.

Erase and re-use

The beauty of this optical disc is that very large amounts of information can be swapped between computers with the ease of swapping data on regular floppy discs. Manufacturers have since produced erasable optical discs where information can be deleted and the disc can then be re-used.

The optical storage of information is very useful as large amounts of text or images can be handled. A new system called CDI is able to store thousands of digitally encoded colour pictures on a single disc. This means that photographic libraries and TV image banks can now consist of discs and disc readers with high-definition screens. Searching for a particular picture takes only seconds.

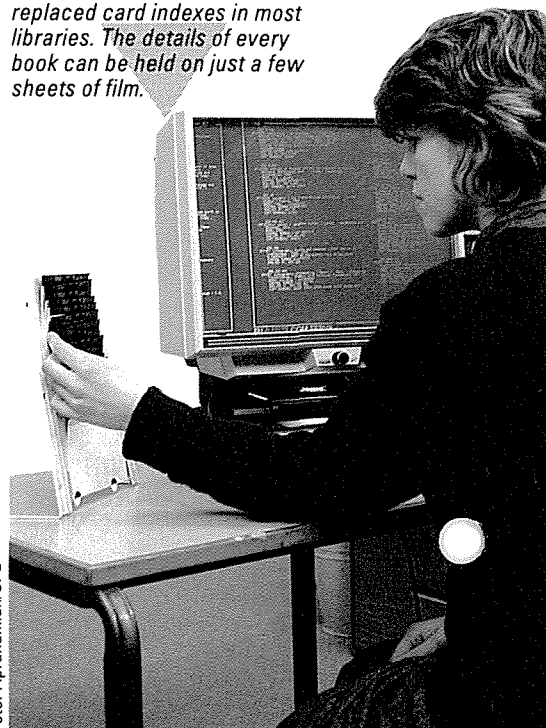
Tiny images can be made using photographic reduction. This technology is familiar in libraries, bookshops and garages, where microfiche readers and books containing sheets of microfiche material are commonly seen. In a microfiche, or microfilm, pages of printed informa-

tion are optically reduced and printed on film.

The amount of information a microfiche can contain depends on the size of the photographic grain but, using this technology, approximately two sentences of printed words fit into about one square millimetre. Linear reductions of about 20 diameters are common.

There is a limitation to this technique, however, even if the finest-grain film were used. Reducing and enlarging optical devices have a resolving power limited to that near the wavelength of visible light.

Microfiche readers have replaced card indexes in most libraries. The details of every book can be held on just a few sheets of film.



Peter Abrahamian/SPL

INTO THE FUTURE

ENGRAVING ON ATOMS

▲ Using powerful electron beams like those in electron microscopes, researchers can move single atoms on the surface of a material.

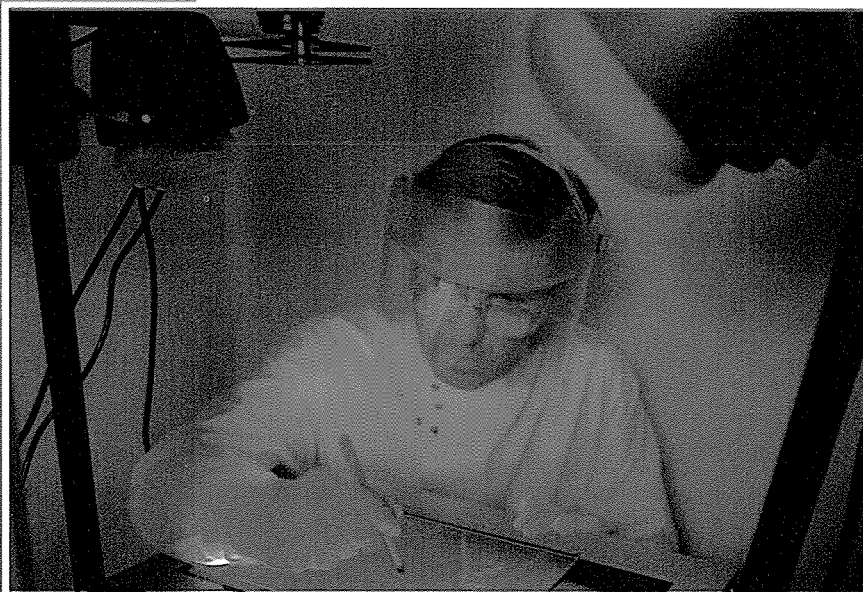
▲ Ultimately it should be possible to move atoms in ones and twos into the shape of minute letters and form words and sentences.

▲ This would mean that you could write every written work ever produced in the history of the world on a piece of paper 3 metres square.

Joe Lawrence



GENE BANK



ICI Agrochemicals M Bare/Rapho/SPL

Plant seeds being identified and separated in a process known as genetic fingerprinting.

Microinjection is a technique for introducing other, or more, DNA into a cell via a very fine needle.

We know next to nothing of the full potential of jungle plants and creatures. It is thought that less than ten per cent of jungle plants have been discovered and recorded: even fewer – about one per cent – have been studied in detail.

Tropical forests contain a vast genetic diversity because they contain so many species and varieties of species. These include the original 'wildtypes' of some of the plants and animals that have been specially bred to be economically useful to mankind.

- WILDTYPES
- IMPROVING YIELD
- NEW FRUIT

TROPICAL RAIN FORESTS ARE an enormous reservoir of life forms. They are a storehouse of genes – the 'chemical blueprints' inside each living thing that carry the instructions for building and running that particular species of animal or plant.

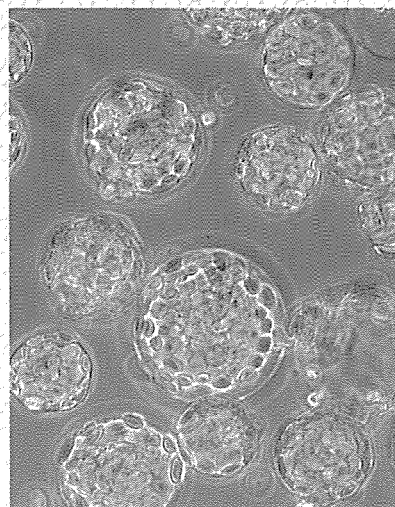
Using modern techniques of genetic engineering, scientists can manipulate these genes. As a result, they are always on the look-out for new genes and novel combinations of genes. The aim may be to produce a cow with a better milk yield, a new way of making a life-saving drug, or a new flavour of tomato.

WEEDING THE GENES

Many rain forest plants, including tobacco (right), have been improved and made more resistant to diseases and pests by certain genetic engineering techniques.

To start with, the tough fibrous outer walls of the cells are chemically removed. The resulting (intact) cells are called protoplasts and masses of these are grown in dishes filled with a sterile growing medium containing organic materials, vitamins and growth substances as required. Normal healthy plants grow from the protoplast cells. To speed up their growth, a very low electric current is passed through the growing medium.

Cloning cells and the process of accelerated propagation are techniques that are essential to genetic engineering.



Sinclair Stammers/SPL



These wildtypes may contain additional genes that could be added to our food crops to make them more resistant to disease, or cause them to produce better yields.

Scientists realized how useful the wildtypes could be in the 1920s, when a disease was wiping out sugar cane plantations in South America. The effects of the disease were stopped by crossbreeding the canes with a wildtype cane from the jungles of Java, which was resistant to the disease. The new hybrid canes had the sugar-producing qualities of the old plantation canes and the disease resistance of the wildtype ones.

In 1970, great areas of the USA's cornfields were blighted by fungus, causing losses of \$2 billion. The problem was solved by crossbreeding the American corn with a Mexican corn that had genes for resistance to the fungus.

The world's cocoa plantations are descended from a few original plants that grew in the Amazon jungle. They have very limited genetic variation. During the 1980s a search was started in the cacao tree's original jungle home for wild-

Christopher Sainsbury/Orpix



A new species is examined by experts who make a detailed description and compare it with other finds using a classification key – a series of questions about the structure. A new find will be given an international name in Latin.

type varieties of cocoa, which might improve yield and resistance to disease.

New varieties of fruits and other produce are also being created. The mangosteen, a new and succulent fruit from the Malaysian jungle – similar to a lychee – is being marketed all over the world.

The household tomato came originally from tropical Ecuador. By

geniengineering' – selecting plants and animals with particular characteristics and breeding them – has been carried out by mankind ever since animals were first herded and the first corn was planted.

Breeding from the cows that gave the most milk and were docile or from the cereals that produced the most grain was the first step to domestication. But it was largely luck whether the desired combination of genes came together.

Today, the techniques of genetic engineering are carried out within cells themselves, under the microscope. An individual gene can be lifted from one cell and inserted into another cell, which may be from a different species. The transfer of genes is done using enzymes and viruses, which 'carry' genes into the cells they infect. The new cell is then made to divide and eventually grows into a new organism.

Genetic engineering is a fairly new technique. Yet, given the vast reserves of genetic material in tropical rain forests, many scientists believe it is potentially very useful.

Dr Nigel Smith/Hutchinson Library



Crossbreeding the sugar cane on the left, suffering from a disease known as rust, with a wildtype has added a gene that makes the crop resistant to rust.

Wheat is one of the many plants that has benefited from genetic engineering, which has produced a crop that can grow in harsh climates and in poor soil.

Philippe Plailly/SPL

breeding the first strain with different wildtype tomatoes, the fruit has been made more resistant to fungus infection, had its shape changed to be more suitable for mechanical harvesting, had extra vitamin C added, and had its colour made a deeper red. Unfortunately, in the course of these changes much of the flavour has been lost.

Wild ox

The kouprey is a wild ox from Cambodia. It is thought to be resistant to rinderpest disease, a highly contagious, viral disease which causes huge losses in herds of Western cattle. But the kouprey is rare and hardly ever seen.

Warfare, logging and clearance for crops is threatening its forest home. Only if the Cambodian jungle is preserved will the kouprey increase in numbers, allowing research into its resistant genes.

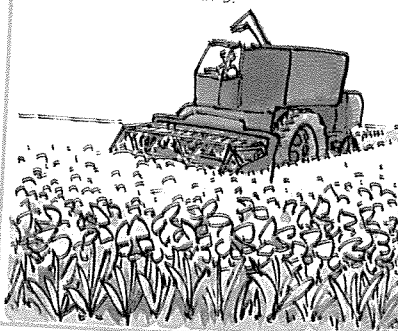
A simple form of 'genetic en-

Paul Raymond

Just amazing!

SPRING CROP

A GENE FROM A MEXICAN WILDTYPE CORN COULD MAKE A HARVESTABLE CROP GROW FROM PERENNIAL BULBS LIKE DAFFODILS OR TULIPS.



HI-TECH SEX

■ EGGS AND SPERM

■ EMBRYO FLUSHING

■ NUCLEAR TRANSFER

TWO FRAGMENTS OF LIVING matter, the egg and the sperm, are essential for the creation of each new life. So the key to the control of reproduction is the ability to obtain, preserve and handle these elements.

The larger of the fragments is the egg, which is formed inside female mammals. Each human egg is about 0.13 mm across and weighs around a millionth of a gram. The male provides the other fragment, the sperm. This is usually much smaller and lighter than the egg, and millions are produced at a time.

One in eight human couples are unable to have children, a condition known as infertility. This is often caused by the inability of the male to produce healthy sperm. In this case, artificial insemination by donor — known as AID — can often help. A quantity of male sperm is placed on the neck of the womb using a syringe: the sperms then enter the womb and one fertilizes an egg in the usual way.

Obtaining the sperms from males is easy. The semen that contains the sperms is simply collected

in glass containers and then tested to make sure that the sperms are active and free from infection. After testing, the semen is mixed with a cryoprotectant — a sterile liquid that freezes below 0°C. This mixture is then slowly cooled to -7°C, just above the temperature at which it freezes.

A laboratory technician then picks up the container of semen using metal forceps cooled in a container of liquid nitrogen. This

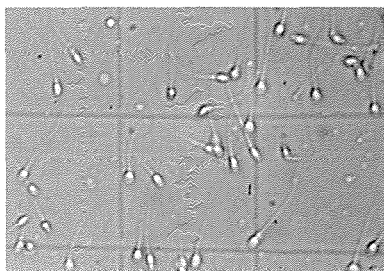


In human in vitro fertilization, a couple of eggs are floated in a glass dish and the sperms are added using a hollow glass tube.

Human embryos are examined to make sure the new life is developing correctly. Only perfect ones are implanted.

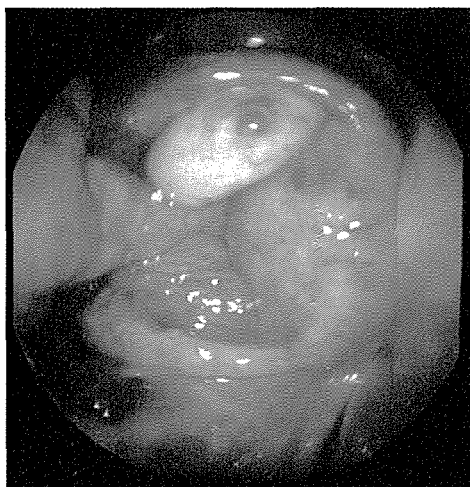


THE SPERM COUNT



Viouard/Frank Spooner Pictures

If a human couple are infertile, one of the first medical checks is to count the number of sperm being produced. Males usually produce about 350 million sperms at a time: if the number of sperms is below 20 million, it is unlikely that the couple will conceive naturally. But numbers are not enough – the sperms must be active. Propelled by their tails, they should move at a rate of up to 3 mm per minute. If fewer than 40% are active, conception is unlikely so couples with this problem often turn to artificial insemination to have a family.



Petit Format/Nestle/SPL

cools the mixture down further, and does so very quickly. As a result, any ice crystals that form in the cells are very small and so do not damage the cell structure. After this initial quick freeze, the sample is again cooled very slowly, reaching -50°C in three to four hours.

The semen is then placed in a flask of liquid nitrogen for long-term storage at -196°C . Human sperm is stored in sperm banks which are equipped with the necessary freezing equipment.

Unknown donors

The men who provide the sperm – the donors – are only allowed to father 12 children in total by artificial insemination, the names of the donors are not known and only the people involved know how the child was conceived.

Infertility also occurs if an egg duct – Fallopian tube – is blocked or the female does not produce mature eggs. This can be confirmed by examining the ovaries and fallopian

tubes through a surgical instrument called a laparoscope. Many women not producing mature eggs are then treated with hormones to help the eggs mature. These hormones are normally referred to as fertility drugs.

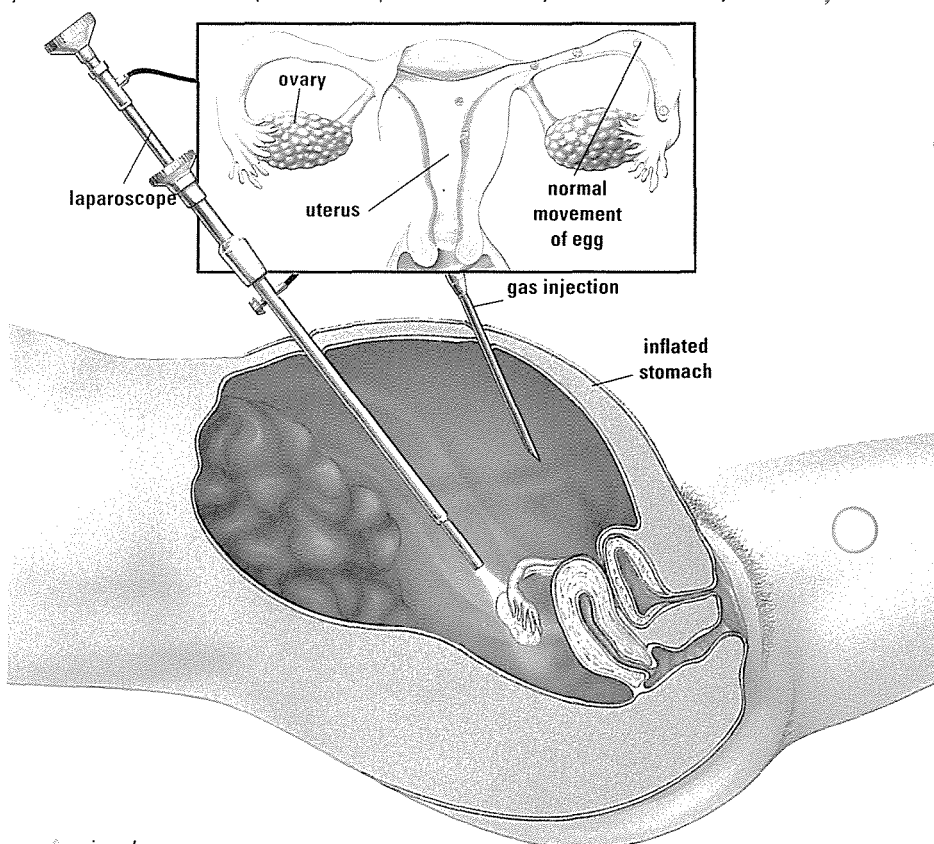
After taking these drugs, most women conceive in the normal way after a few months. But if conception has not occurred after taking fertility drugs for some time and the ovary is definitely producing eggs, another treatment is available.

This process starts off with a ripe egg removed from the female, again using a laparoscope. An egg is simply sucked out of the ripe follicle

on the surface of the ovary and removed through the hollow centre of the laparoscope.

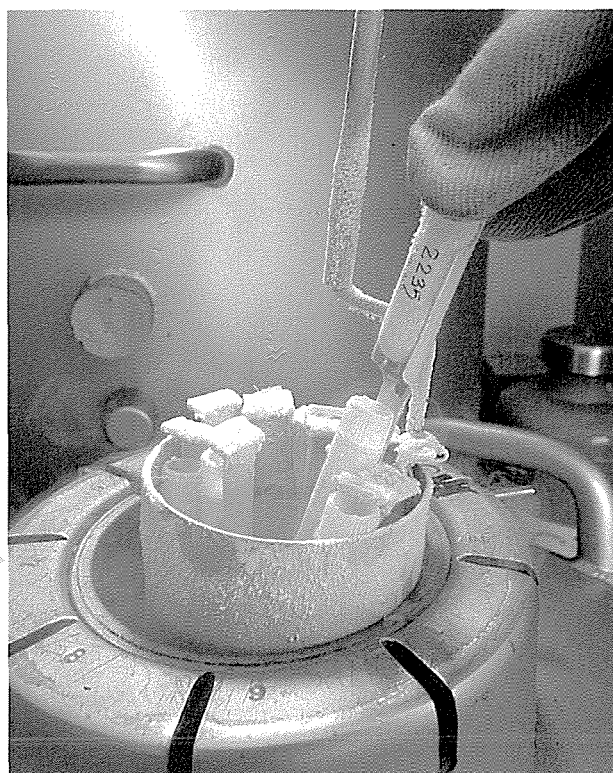
The egg and some active sperms are placed in a shallow glass dish. A technician then jockeys the two elements towards each other until a sperm breaks through the outer coat of the egg and fertilization occurs. As it takes place in a glass dish, this is known as *in vitro* (in glass) fertilization.

The fertilized egg is then placed in the womb of the woman who has produced the egg. In 70% of cases, the egg implants successfully in the lining of the womb and a normal human baby is eventually born.



Laparoscopy involves inflating the abdomen with harmless gas and inserting a tube through a small cut just below the navel. The laparoscope itself consists of a fibre-optic tube through which the surgeon can see the outside of organs such as the ovaries and the fallopian tube (see photo above left which shows follicle on surface of ovary).

Human sperm is stored for long periods in insulated flasks of liquid nitrogen at -196°C . At this temperature, the containers can only be handled using heavy gloves.



Douglas Kirkland/Contact/Colorific



Avoncroft Cattle Breeders Ltd



Selected AI bulls are weighed regularly to make sure that they are in good health and getting enough to eat. Their food consumption is also recorded so that breeders can work out how efficient each bull is at converting food into meat. Many bulls are pure bred, like this Hereford, but cross-breeds are also used.

Babies conceived in this way are known as 'test tube babies'.

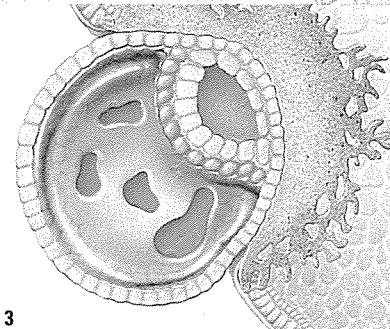
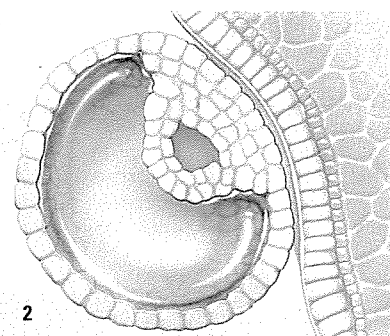
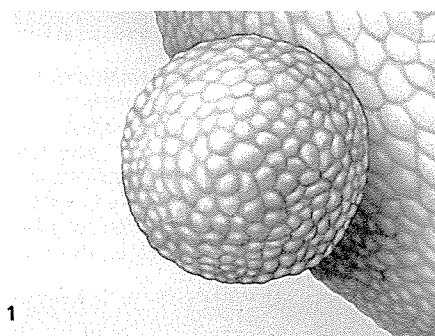
Artificial insemination — AI — is an important part of the farming routine. Livestock have been selectively bred for thousands of years by using only the best males for breeding, but now various organizations collect and store the sperm from selected bulls. In contrast to the unknown human sperm donors, very careful records are kept of the bulls which provide the sperm.

For example, farmers might want to create cows with more meat on them, or to improve their milk yield. These factors are carefully measured, so a farmer can take his or her pick of the most suitable bulls.

Once the choice has been made, a dose of frozen sperm is ordered

and a farmer can either place it in the cow himself or ask an AI technician to do the job. The frozen sperm arrives at the farm in a paper straw and is quickly thawed in warm water just before use.

John Houghton



An embryo grows into a group of cells known as a morula by the time it reaches the womb or uterus (1). Up to this point it is simple to remove the embryo from the mother either by surgery, or by flushing, in the case of some animals. The cells are then re-arranged to form a hollow ball known as a blastocyst (2). This starts to pick up nutrients from the womb lining and steadily burrows (3) into the womb lining, until it cannot be removed without destroying the future life.

Embryo flushing is normally done by a team of vets. The sterile fluid is injected into the womb and allowed to drain back into a container. Apart from a slight discomfort, the cow does not suffer.

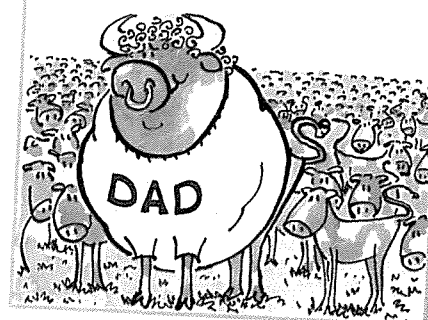
Geoff Tompkinson/Aspect Picture Library



Just amazing!

A LOAD OF BULL

ONE BULL'S SEMEN OUTPUT FOR A YEAR IS WORTH UP TO £1 MILLION AND WILL FERTILISE UP TO 100,000 COWS.



Paul Raymond



This is a quick way of improving the quality of a herd because the fertilized embryos are implanted in healthy but unproductive cows. The resulting calves will then have the characteristics of the choice animals that provided the sperm and the egg, not of the animal that actually gave birth. Another advantage of this method is that it is non-surgical, so the cows do not get upset and the success rate is therefore high.

Immature eggs

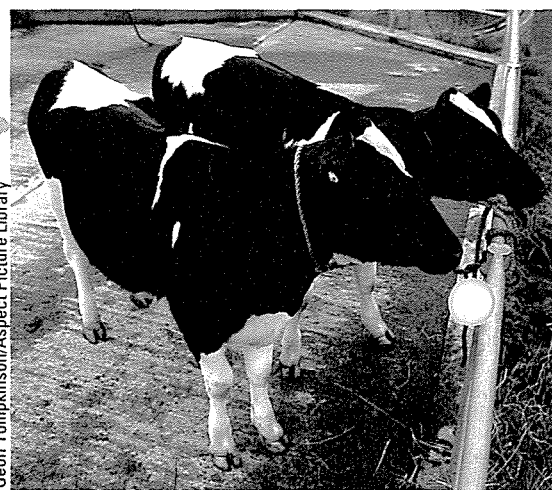
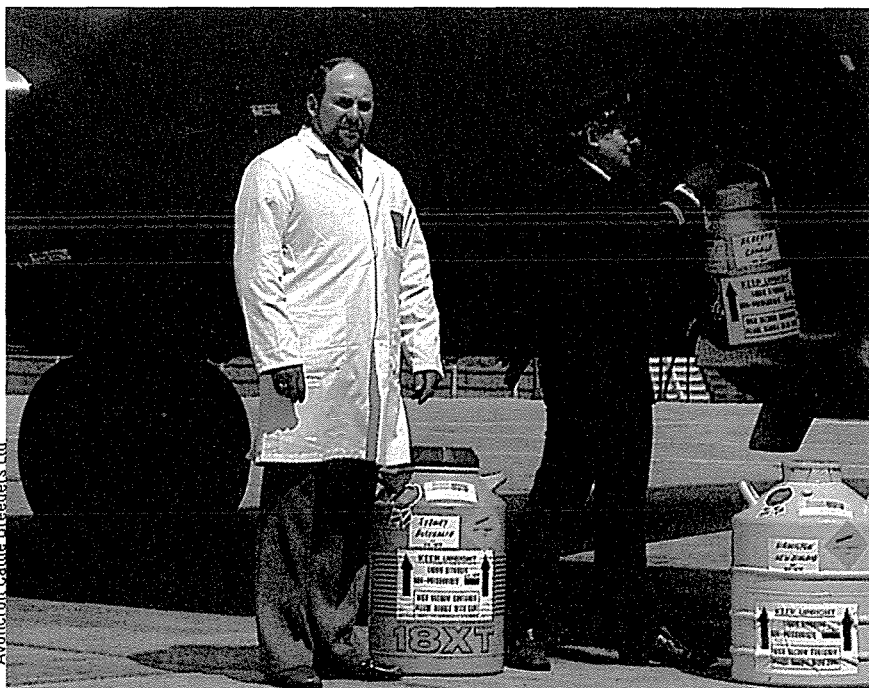
Several new reproductive techniques are now being developed, mainly for cattle. One of these is *in vitro* maturation. A cow – usually an old one – will be selected and sent for slaughter. The ovary will be removed from the carcase and large numbers of immature eggs extracted from the ovary. These are placed in a liquid containing similar foods to the ones supplied to the eggs in the ovary. The eggs go on growing and microscopic examination reveals when they are mature and so ready for *in vitro* fertilization. The fertilized embryos are then implanted in a suitable cow.

Another technique of the future is the division of a normal fertilized egg into two separate embryos. Soon after fertilization, the nucleus

Semen for export is tested with extra care to prevent cattle diseases being spread from country to country. It travels in insulated containers.

Embryo splitting produces cows which are clones of each other. Nevertheless, minor differences, such as different-shaped patches, do appear.

Avoncroft Cattle Breeders Ltd



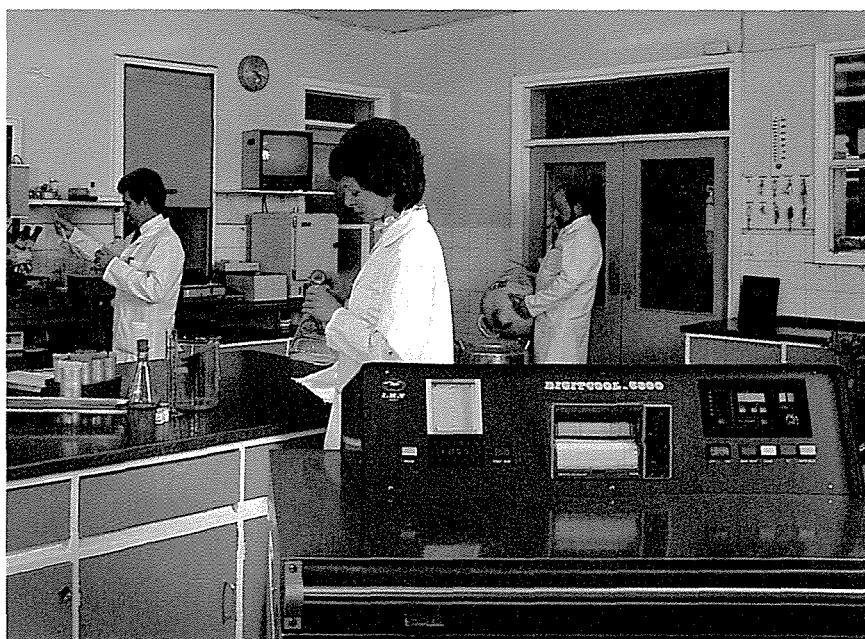
Geoff Tompkinson/Aspect Picture Library

All the genetic information of the superior animal is in the chromosomes packed into the transplanted nucleus. The new cells develop into identical embryos.

Life is normally thought of as fragile and easily damaged. But these reproductive techniques are becoming routine, so eggs and sperm must be tougher than we sometimes think.

SEXING EMBRYOS

Farmers sometimes want female calves for milking; at other times they might want male calves for fattening up ready for slaughter. Embryos for transplantation can be tested for their sex before being implanted in their new mothers. A special dye is added to the embryo container. If the embryo is male, the dye will cling to the outside of the cell coat and stain it. Perhaps the researchers could fix it so that embryos are coloured blue for a boy, pink for a girl.



Avoncroft Cattle Breeders Ltd

Semen doses are tested and diluted with sterilized skimmed milk, then frozen in a computer-controlled freezer unit.

of the egg divides into two, each part with a full set of chromosomes.

Under a microscope, this single cell can be cut in half with a small piece of razor blade leaving one nucleus in each half of the cell. New cell membranes form round each half egg and these grow into separate but identical embryos, ready for implantation. The embryos grow

into two separate but identical animals, each one a clone of the other.

In theory, each of these new embryos could be divided again and again, but this does not always work. Another technique, which is likely to be more successful, is nuclear transfer. In this, the original embryo produced by a selected bull and cow is allowed to go on growing until it is a cluster of cells. Several of the nuclei of these cells are then removed and microinjected into ordinary cattle eggs from which the original nuclei have been removed.



TIME TRAVEL

IN THE 21ST CENTURY, a starship returns to Earth from a mission to the star Wolf 359, which lies 7.5 light years away. The ship's log records a successful trip lasting 15 years, with the ship cruising at 99 per cent of the speed of light. On board, all is well.

But crew members cannot recognize any of the faces among the crowd assembled to greet them. For back on Earth, 106 years have passed during the voyage and the crew's families and friends have all died. . . . The reason is that time on the swiftly speeding starship has been passing seven times more slowly than on Earth. The ship's crew have travelled into the future.

Starship time

This is not the product of a science fiction writer's imagination — it would really happen, according to the laws of nature. Aboard the starship, time is measured by clocks, all of which indicate that only 15 years have passed on the trip. No one aboard the spaceship would notice any difference from normal time on Earth. Bodily processes, such as the rate of their heartbeat and ageing, would also slow down by the same amount as their wristwatches. Only when

they returned to Earth would the results of the time difference become noticeable.

The key to understanding this difference is the speed of light. Light always moves at 300,000 km per second — the fastest speed in the Universe. You would always measure the speed of a beam of light to be 300,000 km per second, no matter whether you were moving towards the source of the light beam or away from it.

Speed of light

This appears to defy common sense. For example, if you measured the speed of an object such as an oncoming car, the closing speed would be equal to your speed plus the speed of the oncoming vehicle. But that does not work in the case of light. Your own speed does not affect the speed at which light is moving relative to you.

Earlier this century the physicist Albert Einstein realized that if the

Time travel is still a fiction for Man, but modern ideas about the Universe depend on the way time speeds up and slows down.

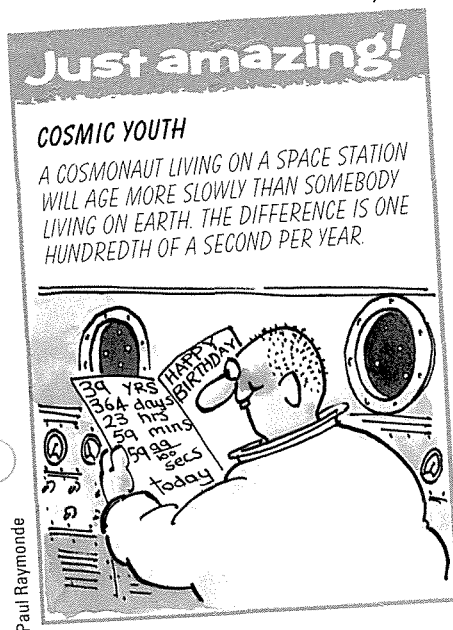
speed of light is constant, then the passage of time must be variable, depending on your speed. He concluded that the closer you travel to the speed of light, the slower time passes. This effect is known as *time dilation*.

In the case of our imaginary starship cruising at 99 per cent of the speed of light, time would pass at one-seventh the rate that it does on Earth. At the speed of light itself, time would stand still — but, according to Einstein's theory, it is impossible ever to reach the speed of light. It is the speed limit of the Universe.

As time slows down, other effects come into play, too. The length of the starship — and of the objects and people inside it — becomes shorter in comparison with



Stephen Hunt/Image Bank



their length back on Earth. What's more, the mass — known as weight on earth — of the starship and its contents also goes up. The same factor that governs the slowing of time also applies to the shortening of length and increase of mass.

As the speed of light is approached, length shrinks towards zero and mass increases towards infinity. As with the slowing of time, the people on board the spaceship notice nothing abnormal since

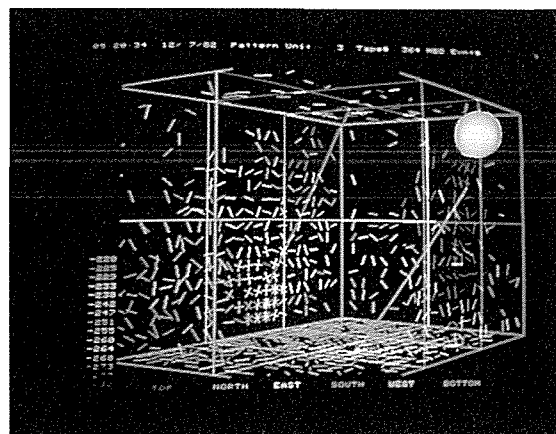
SLOWING TIME

Time slows down as we approach the speed of light. This table shows how much time would slow, relative to clocks on Earth, at various percentages of the speed of light.

Percentage of the speed of light (relative to Earth)	Amount by which time is slowed, relative to Earth
0	1.000
10	1.005
20	1.021
30	1.048
40	1.091
50	1.155
60	1.250
70	1.400
80	1.667
90	2.294
95	3.202
99	7.089
99.9	22.361
99.999	223.607
100	Infinite

A STRETCH IN TIME

The slowing of time at high speeds is shown by tiny particles, smaller than atoms, called mesons. These occur when cosmic rays strike the Earth's upper atmosphere. Mesons have a lifetime of two millionths of a second, during which time they travel about 600 metres — nowhere near enough to reach the Earth's surface. But time dilation enables mesons to reach the surface, where they can be detected by a cosmic ray detector (right). To a meson travelling close to the speed of light, the 40km of the earth's atmosphere is no more than a few hundred metres deep.



everything is changing by equal amounts.

At normal everyday speeds on Earth, such as in a car, these effects are so tiny as to be totally unmeasurable. Even a spaceship orbiting the Earth moves at only about one forty-thousandth the speed of light.

Cosmic rays

However, we can see the effects of time dilation at work in the case of atomic particles that are travelling close to the speed of light. These particles come from space in the form of cosmic rays. (We can also speed up atomic particles in machines on Earth called particle accelerators.) Such fast-moving particles have a much longer life-

span than normal and an increased mass — as predicted by Einstein.

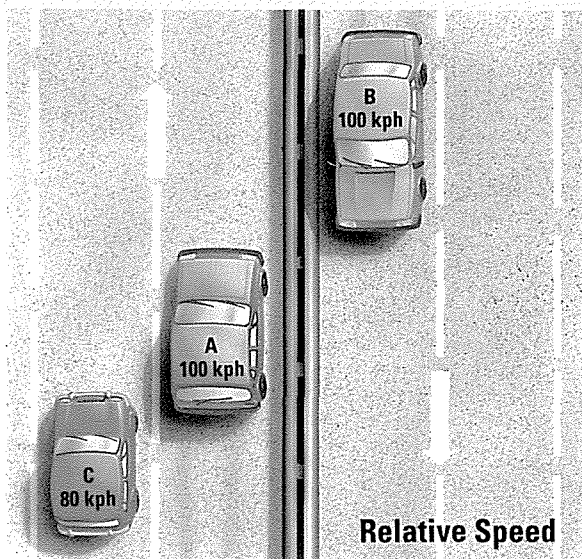
If we could travel as close to the speed of light as these atomic particles, time on our spaceship would slow down so much that we could cross the Galaxy in a human lifetime. Back on Earth, 200,000 years would have elapsed.

Therefore high-speed space travel offers a form of time travel, with potentially bizarre results. For example, you could take off on a trip lasting 60 years of Earth time. When you returned, you might have aged only a few years — yet your son, only a toddler when you left, would by then be an old man!

This form of time travel, however, is fast forward only — into the future. There is no going back.

Larry Sulak/SPL

THE CONSTANT SPEED OF LIGHT

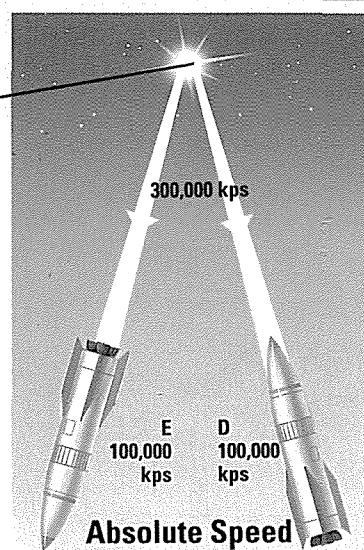


Imagine that you are driving along a motorway. If you were travelling at 100 kph (kilometres per hour) in car A and car B came towards you at 100 kph, the two cars would approach each other at 200 kph.

If car A continued moving at 100 kph and overtook car C travelling at 80 kph, the difference in speed would be only

20 kph. So although car A is always moving at 100 kph, its speed *relative* to other cars depends on the direction they are moving in.

However, suppose you were in starship D, travelling towards the star Wolf 359 at 100,000 kps (kilometres per second). If you measured the speed of light from the star coming towards you,



you would get a reading of 300,000 kps. And if somebody on starship E speeding away from Wolf 359 at 100,000 kps measured the speed of light, they would also find that light from the star came towards them at 300,000 kps. So the speed of light is *constant* no matter what direction you happen to be travelling in.

Caroline Brodie



WATER POWER

 TURBINES

 TIDAL POWER

 DAMS

ANCIENT WATERWHEELS have been transformed into huge modern turbines. These lie at the heart of hydroelectric plants driven by water power — the most economical method of generating electricity.

Hydroelectric turbines are powered by the huge reservoirs of water held back by dams. As the water falls through the power station, the turbines turn and electricity is generated.

Hydroelectric power is clean, inexpensive and safe. Some countries, notably Norway, derive nearly all their electricity from this natural source.

About five different dam designs are in common use today. They range from the 'solid gravity' design of the world's highest dam in Tajikistan which resists the massive pressure of the water behind it

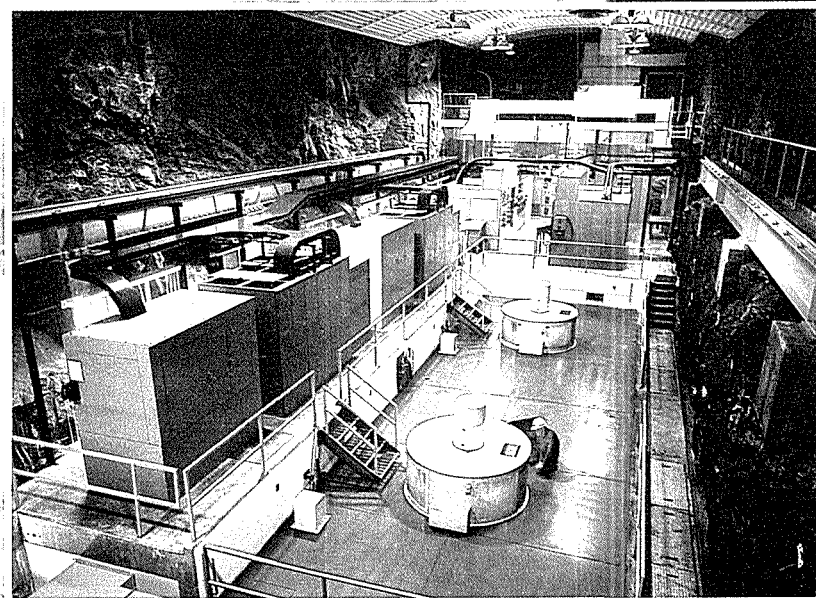
simply by its huge mass, to the cupola dam which has great strength because of its curved shape. Cupola dams are usually built across narrow valleys; the curve of the dam directs the huge thrust of the water into the solid rock walls of the valley.

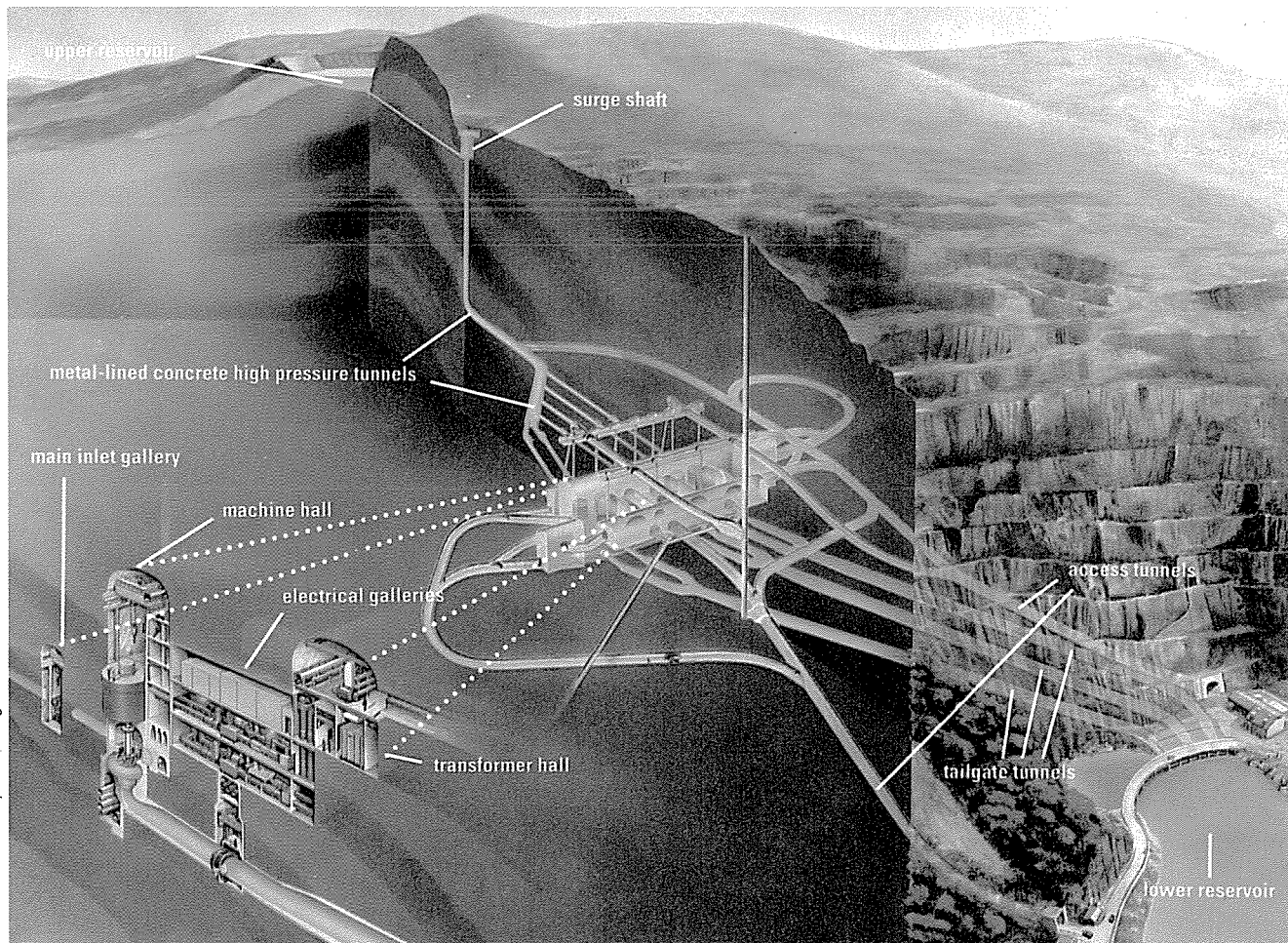
More than one type of turbine is used. Reaction turbines are the most powerful. They have propeller-like blades inside a curved outer casing and are completely immersed in the stream of water.

Under pressure

If the volume of water is not large but comes at a high pressure because it falls from a great height, an impulse turbine is used. This type is called a Pelton wheel. The wheel is driven round by the impulse, or force, of water jetting into cups arranged around the turbine.

Niagara Falls was harnessed by the world's first ever hydroelectric power station. The turbine room of the modern hydroelectric power station at Snettisham, Alaska, (inset) can produce over 47 megawatts, enough to serve a small town.





The pumped-storage power station at Dinorwic, Wales, uses turbines to pump water up to the top reservoir. Running it back generates electricity.

Water turbines can also be used to generate electricity from the power of the tides. The only large tidal power station is on the estuary of the River Rance, in Brittany, France, which has an average tidal range of over 8 metres. A dam across the estuary holds back the water, creating 'a head' to drive the turbines.

Some tidal systems have a double action, rotating the turbine in one direction when the tide flows

in, and in the opposite direction when it ebbs. Other systems use only the ebb (outgoing) tides.

Although huge ocean waves carry with them massive amounts of energy, no cheap and easy way of recovering it has yet been devised.



Wave force

However, small-scale, experimental schemes have been put into practice. A prototype 'oscillating water column' wavepower generator is to be built on the Island of Islay, off the west coast of Scotland.

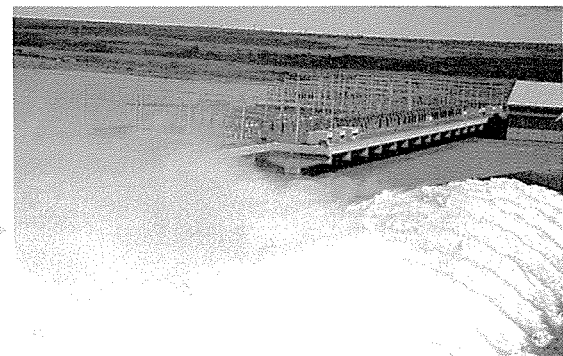
The column is a chamber submerged and open to the sea at the bottom. As waves wash past, the

water inside moves up and down like a piston, driving the air above in and out through a turbine. A system of valves makes sure that the turbine always turns the same way. The turbine itself is connected to a generator which creates electricity.

The prototype on Islay will generate 180 kW, enough to supply local houses at 4p a kWh, 35 per cent cheaper than electricity on the mainland.

Coal-fired, oil-fired and nuclear

ZIFA

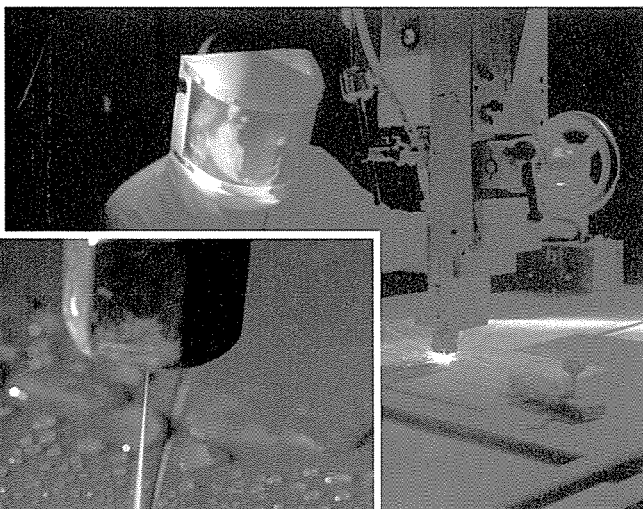


Hydroelectric dams generate electricity, which is controlled by a complex system of transformers and switchgear.

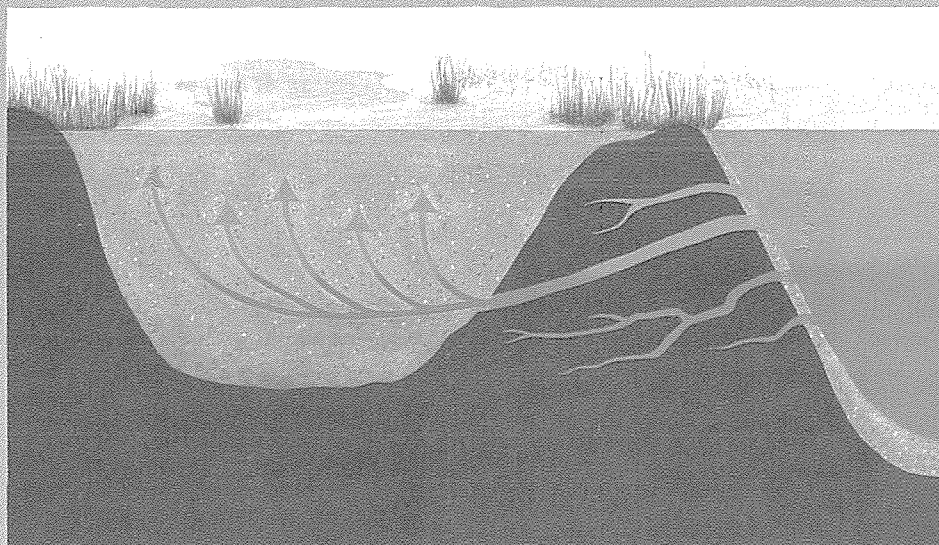
Jets of water containing fine particles of the gemstone garnet can cut through aluminium. The water cools the metal as the particles cut it, so the edges are not distorted by friction.

power stations rely on turbines to harness the power of steam produced in boilers into electricity. These enormous steam turbines are driven by high-pressure steam at high temperatures. The steam entering turbines is around 550°C and the pressure as high as 350kg/sq cm.

In the 60 Hz system used in the USA, turbines run at 3,600 or 1,800



THE SECRET OF QUICKSAND



There are few more horrible deaths than being drowned in quicksand. Ground that looks solid suddenly gives way, sucking you down into crushing, choking extinction.

But quicksand is living testimony to the power of water. It is not simply a pit of dry soft sand. Nor is it wet sand that is just particularly soggy. Quicksands are created when water from an underground spring forces its way up through a pit of sand. The water pressure forces the grains of sand to separate slightly, turning normal sand, which is safe to walk on, into an inescapable, crumbling, sinking hell.

Caroline Brodie

rpm (revolutions per minute). In the 50 Hz systems used in Europe, speeds are 3,000, 1,500 and 1,000 rpm. At such speeds, steam passes through the entire turbine in less than 1/30th of a second – the time it takes to blink.

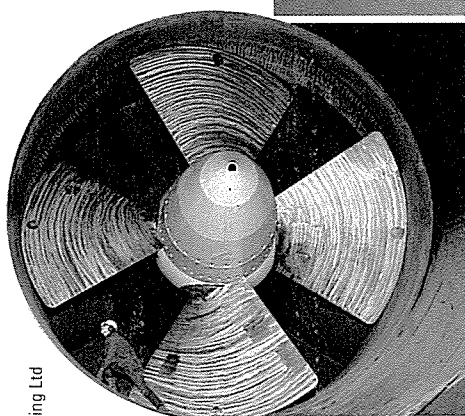
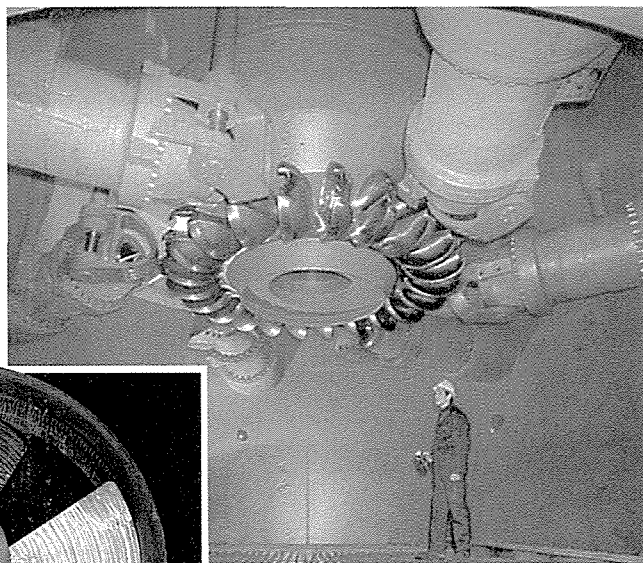
The amount of energy supplied to a hydroelectric power plant is determined by the volume of water stored behind the dam or natural

One way around this is to use pumped-storage, as at Britain's new plant at Dinorwic in Wales. The plant is sited in mountains close to two lakes located at different heights.

At night and during other off-peak periods, surplus electricity is used to power pump turbines which raise water from the lower lake to the upper one. During the day, when demand for electricity is

ZIFA

An impulse turbine is turned by high-pressure water jetting into its cups. A reaction turbine (inset) is submerged in the stream and is turned by the water rushing past it.



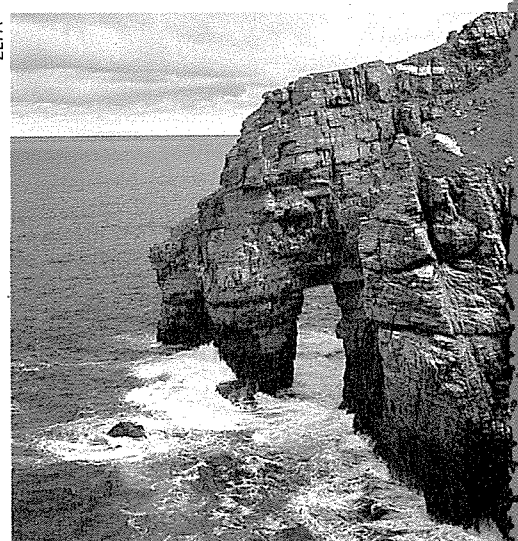
Kvaerner Boving Ltd

reservoir. When the demand for electricity is low, water passing through the turbine is wasted and any electricity generated unwanted. Shutting down the turbine is time consuming and uneconomical. The problem is that, as yet, there is no method of effectively storing large amounts of electricity.

high, the water is allowed to fall again from the top lake down into the bottom one through the turbines, generating extra power just when it is needed.

Hydrogen fuel

Hydrogen is the most abundant element in the universe, and it can be made by splitting molecules of water, which release oxygen at the same time. Already liquid hydrogen is used as a fuel in the main engines of the Space Shuttle and in other space rockets. However, this cheap, clean fuel could have more widespread applications on Earth.



The power of the waves is enough to crumble even solid rock. They force air into cracks with explosive power.

Kvaerner Boving Ltd

Just amazing!

PELLETS FROM HEAVEN

SEEDING CLOUDS WITH PELLETS OF DRY ICE CAN SET OFF RAIN OR SNOW STORMS. A SINGLE PELLETT FALLING THROUGH A CLOUD 1 KM THICK COULD PRODUCE AS MUCH AS 100,000 TONNES OF SNOW.



Paul Raymond

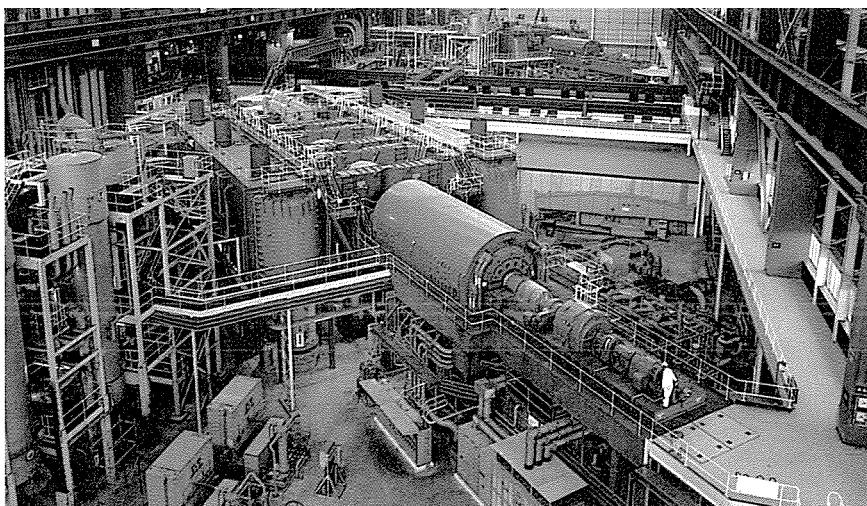


In Russia, scientists are experimenting with liquid hydrogen for use as an alternative fuel in Tupolev airliners. Burning the liquid hydrogen poses no special problems – it combines with oxygen to form water vapour and give a clean, hot exhaust.

Fuel space

Although liquid hydrogen burns cleanly and causes less engine wear, it unfortunately has certain disadvantages. It takes up four times as much space as liquid aviation fuel, so aircraft need extra

NEI Parsons Ltd



Central Electricity Generating Board

The main shaft of a steam turbine rotates at about 3,000 revs per minute. It takes about an hour to reach this speed. Full electrical output is reached in 12 hours but the shaft gets so hot that if it were stopped suddenly, it would bend. To prevent this, the turbine is cooled over four days.

Each steam turbine at the Drax coal-fired power station in Yorkshire, England can generate up to 660 megawatts at full power.

a rock formation, often exposing deeper layers in its structure.

Where water freezes in rock cracks, it can split off tiny flakes or even large boulders. And, on a larger scale, huge glaciers of ice slowly and relentlessly slide downhill, grinding the rock away.

Breaking rocks

At the shore line, crashing waves can exert enormous force on cliffs. Waves can move boulders weighing more than 1,000 tonnes from rock faces by compressing air into cracks in the rock. The air expands with explosive force.

Erosion by water has also been developed into a new tool. Abrasive gemstone particles in a water jet can cut through aluminium. Although a gemstone abrasive cuts by friction, the water cools the cut, preventing heat distortion.

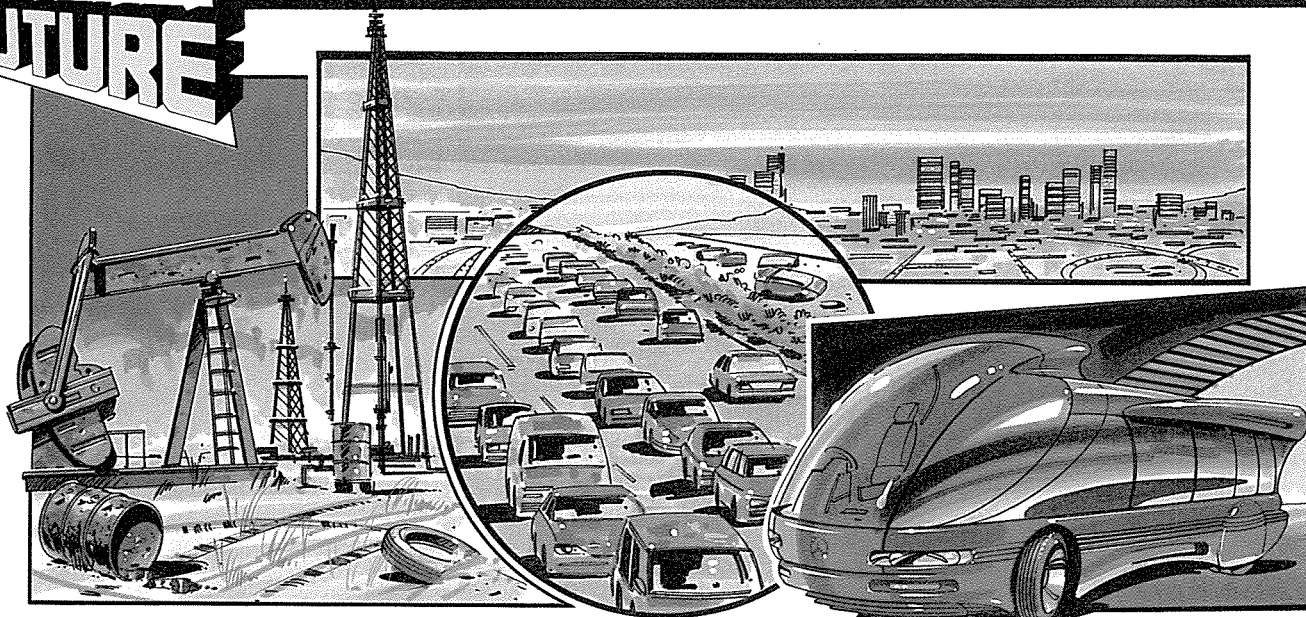
large tanks. It also has to be kept at very low temperatures indeed – well below its boiling point, which is -253°C . It would also be possible to run cars on hydrogen. Manufacturers have designed prototype cars, but the size and capacity of the fuel tank have again posed difficulties – along with the problems of insulation and safety.

Water power can also sculpt mountain ranges that were thrust up by enormous underground forces. As soon as they were formed, wind and rain and other weathering agents set about carving or smoothing them into the shapes we see today.

Rain water wears away the surface where it runs over it. In time, a fast-flowing river cuts a deep 'V' in

INTO THE FUTURE

RUNNING ON WATER



▲ The Earth's reserves of fossil fuels, like coal and oil, will one day run out. So there will be no petrol to run cars.

▲ Burning hydrogen which is derived from water, is a good alternative and – unlike petrol – it is non-polluting.

▲ Experimental vehicles have already been built, with hydrogen-burning engines, which are 50 per cent more efficient than diesel.

Joe Lawrence



 SAMPLING SOUND

 MIDI REVOLUTION

 WEIRD SYNTHS

New synthesized music rivals a traditional orchestra in its fullness and the complexity of sound. Equally amazing, an orchestra of electronic instruments may be controlled by just one musician.

SYNTHETIC SOUND

ZEEA

NEW MUSICAL TECHNOLOGY has revolutionized music making. A synthesizer can produce the sound of a church organ, of breaking glass, of a trumpet, or electronic sounds no human ear has ever heard before – or all these together.

A synthesizer is an electronic instrument that can remember instructions and on which sounds can be edited. It puts together the things that make up a sound. (To synthesize means to put things together.) It is usually keyboard based.

Any sound has four essential qualities:

- **pitch** – how high or low a note is
- **timbre** – the character of the sound (what makes a saxophone sound different from, say, a violin)
- **volume** – how loud the sound is
- **envelope** – how its volume and timbre change over the time it is heard.

Shaping a note

Not only does a synthesizer put these components together, it also alters them so that exactly the sound the player is after is pro-

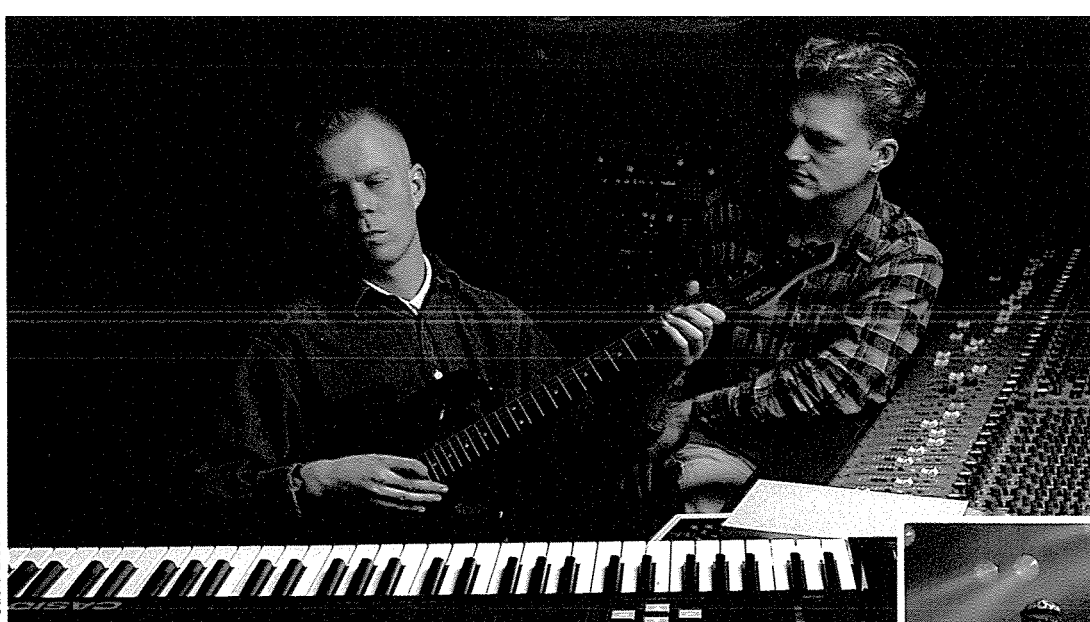
duced. It then transmits the sound, in an electrical signal, to the amplifier and speakers.

An analogue synthesizer shapes each sound by taking away the unwanted elements of the basic waveform. When playing an analogue synthesizer, the most important controls, which shape the pitch, timbre and volume of the note, are:

- **the Voltage Control Oscillator**, which produces the original sound when a key is pressed on the keyboard.
- **the Voltage Control Filter** is

David Redfern





'Synth-pop' groups are products of the synthesizer revolution. Erasure (Vince Clarke and Andy Bell) and Pet Shop Boys (Chris Lowe and Neil Tennant, below) both consist of one musician, who plays all the music on a synthesizer, and a vocalist.



P. Frischmuth/Redferns

then set to filter out some of the frequencies that make up the original wave. This gives the sound its 'timbre' — its individual character.

• **the Voltage Control Amplifier** controls the volume of the note.

As a key is pressed, the sound created quickly rises in volume, and

then the volume drops slightly. The sound is sustained as long as a finger continues to press down the key. When the key is released, the sound fades away. How the volume of the sound changes is controlled by a 'volume envelope generator' within the VCA. An envelope generator within the VCF controls the development of the timbre of each sound.

SPEAKEASY

Synthesizer: an electronic instrument that creates sound electronically and on which sounds can be edited

Analogue synthesizer: every change in a sound is caused by altering an electric current

Digital synthesizer: every sound is chopped up and stored as a string of ones and zeros called binary digits or 'bits'

MIDI (Musical Instrument Digital Interface): a communications system by which electronic instruments, samplers and sequencers can send information to each other

Sampler: a machine that records a sound and plays it back

Sequencer: a machine that records a sequence of key depressions and plays it back.

Music by numbers

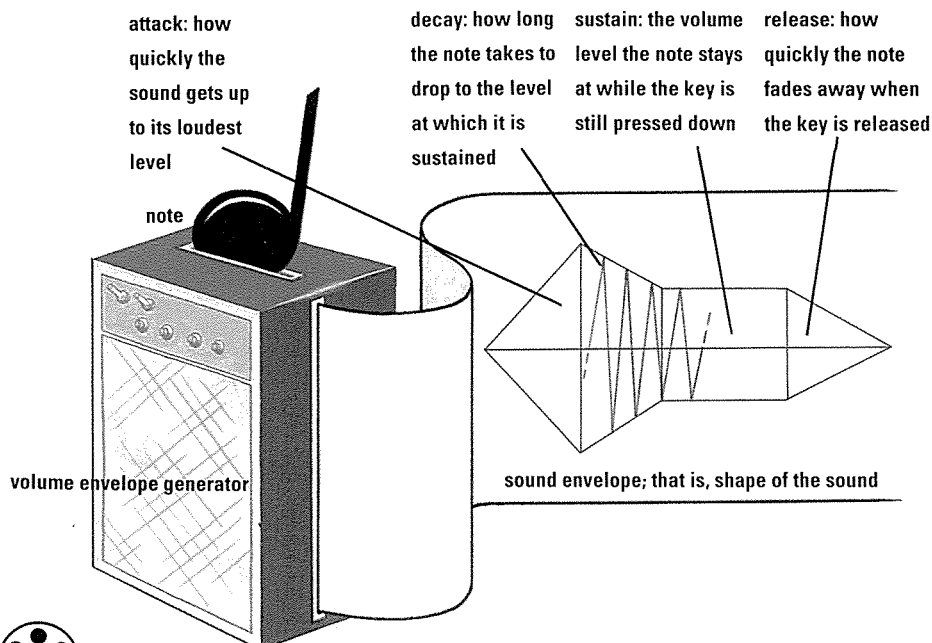
The latest synthesizers are digital. These store and produce sound digitally — as a series of numbers. A digital synthesizer builds a sound up, by adding wave on to wave, to get the effect that is wanted.

There are several ways that digital 'synths' can operate. One is by using Fast Fourier Transform (FFT). This is a method whereby notes are broken down with great accuracy into the frequencies that make them up. FFT enables you to define a

sound, and then to change any details so that precisely the desired effect is obtained.

Another digital method is FM — frequency modulation. FM synthesizers work by using waveforms as 'operators'. You set the first operator so that it sends out the first waveform. Next, you add the second operator, which has been set to give a different waveform. Putting the two together creates a new, complex waveform. You can keep on adding operators, up to a maximum of six, until you get the desired result — the exact sound

A volume envelope generator is a device that shapes the rise and fall of a note. It controls the four phases of each sound: attack, decay, sustain and release.



SOUND AND VISION

These days you can do more with a compact disk than just listen to it. Among the most exciting uses of CDs at the moment are the following:

• **CD-ROM:** The CD has a prodigious data storage capacity — up to 600 megabytes or more — and this facility is now being widely used to store the texts of books, encyclopedias, and published data of all kinds. The resulting disk is called a CD-ROM (Compact Disk-Read Only memory).

• **Multimedia CD-ROM:** This advanced version of the CD-ROM is capable of recording speech, music, animations and video and movie footage.

• **CD-i:** This is an interactive version of CD-ROM which allows you to influence what happens on screen.

• **Photo CD:** Typically 100 of your favourite photographs can be recorded as digital signals on a CD.

• **CD Mini Disk:** This pocket-sized CD system uses a disk only 64mm in diameter. You can record on the Mini Disk, as well as play it back.

Thanks to MIDI, a sequencer and a sampler may be bought separately, from different manufacturers, (as you can afford it) and plugged into one system, which you control from a MIDI keyboard. Or sampler, sequencer and keyboards can all be combined in one streamlined, integrated system.

Roland (UK) Ltd

Roland (UK) Ltd

Yamaha

Roland (UK) Ltd

COMPUTER ON PIANO



Donna Coveney/MIT Media Lab

An instrument can now be played in a live performance – by a computer. In one concert, Lucy Stolzman played the violin and a computer accompanied her on the piano.

How was it done? A digital recording was made of a pianist playing the keyboard part and the recording stored in the memory of a computer. On stage, beside Lucy Stolzman, stood a piano, on which the computer played back the

recording.

But how did the computer know when to join in? It picked up the sound from the violin, pinpointed the exact note on which to come in, and began to play. It was important, therefore, that Lucy Stolzman did not play too differently in pace and style to how she played when the accompanist was being recorded by the computer a few hours before the concert.

that you want. Each operator has its own envelope generator, so that the character and volume of each sound can be very carefully controlled.

Sound appeal

Every make of synthesizer has its own individual sound. In general, the older analogue synthesizers have a full 'fat' sound (which musicians often prefer) compared to the clean, sharp notes of most digital machines. Analogue-digital hybrids have been built by adding a micro-processor to an analogue synth.

A 'sampler' can be a separate piece of hardware or part of a digital synthesizer. Samplers are actually digital sound recorders that record 'real' sounds. The recording, for example, of a musical instrument, can be rearranged as desired, then played back as part of a musical composition.

Making tracks

You can build your own song, using samples of any instrument you want. This is done on many hit songs in the charts today. Sampling increases the range of a synthesizer from electronic sounds to every 'natural' sound that can be recorded.

Synthesizer manufacturers got together and devised a system called MIDI – Musical Instrument Digital Interface – so that synthesizers or electronic instruments, such as



drum machines, could be linked together, regardless of make. MIDI consists of cables through which commands can be transmitted. Each end of the cable can be plugged into a different machine.

Fingertip control

MIDI possesses 16 communication channels – an instrument must be tuned to the correct channel, or it will not receive the instructions that are being transmitted along the cable. Each channel can transmit

sequence of 'key depressions' on an electronic instrument, the sequencer 'plays' the electronic instrument, telling it what notes to play, how hard and for how long. When building up the backing track for a song, a sequence can be stored for the drums, the bass, and the keyboards – in fact up to an incredible 200 tracks on some of the latest sequencers.

Using MIDI, electronic instruments can play all the different sequences together. The effect

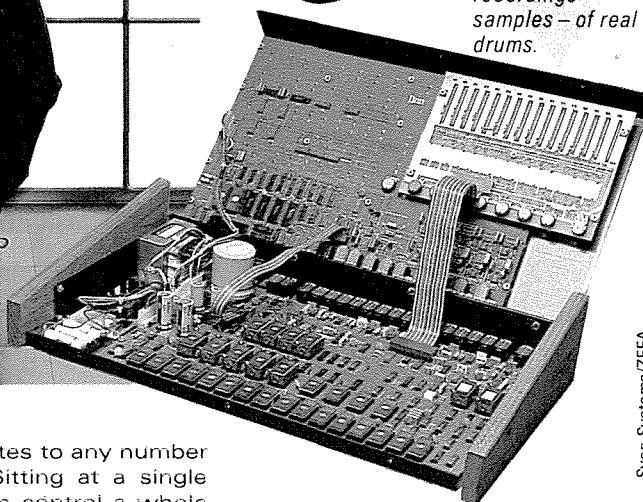
With a guitar synth you can play electric or acoustic guitar, or jazz organ, or even the trumpet. When plugged into MIDI, the guitar can control other instruments.



Casio Electronics Co Ltd

One digital horn can reproduce the sounds of a saxophone, trumpet, oboe, clarinet or flute.

A drum machine uses digital recordings – samples – of real drums.



Syco Systems/ZEFA

any number of notes to any number of instruments. Sitting at a single keyboard, you can control a whole orchestra of electronic instruments.

Another piece of hardware, which can also be built into a digital synthesizer, is a sequencer. Like a tape recorder, a sequencer will record anything played on it via a keyboard. However, unlike a tape recorder, it does not record the sound of the notes. It records the information that you give when you press a key; that is, what note is pressed, how hard it is pressed and how long it is pressed. This information can be stored in the sequencer's memory.

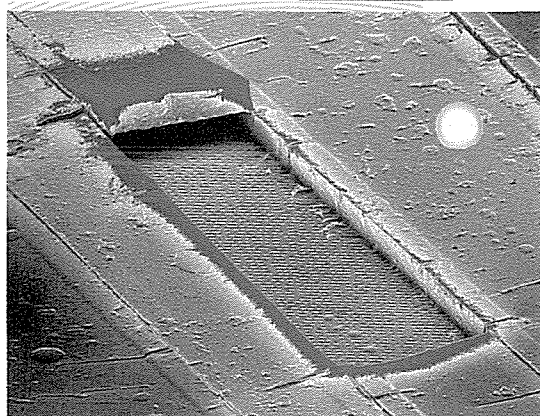
As you play back the recorded

sequence, it resembles a group or an orchestra. So when you hear a piano, a brass section and a string section over bass and drums on a chart hit, the instruments may have originally been sampled, and exist only as data on a sequencer.

Good vibrations

Synthesizers do not necessarily have a keyboard. There are also guitar synthesizers – like some keyboard synths, these can be slung around the performer's neck, giving him or her the freedom to walk around.

INSIDE A COMPACT DISC



Dr Jeremy Burgess/SPL

False colour scanning electron micrograph of a compact disc cracked to show the base layer below the outer plastic covering. The base layer is made of plastic, which is pressed with a series of fine depressions. Each depression represents a digital musical signal capable of being read by a laser beam. To reflect the laser light, the base layer is coated with a fine film of metal, which follows the depressions exactly. This layer is covered by another layer of transparent plastic. The base layer is sealed between two layers of plastic, which prevent dust and scratches from affecting the sound when the CD is played.

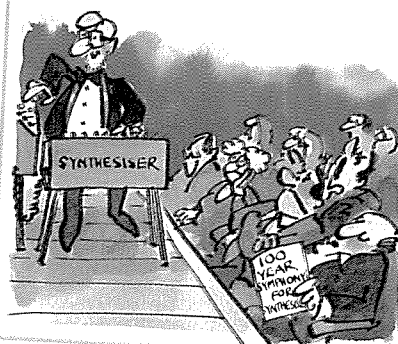
There are even wind synthesizers, which look like saxophones. In these, the air vibrations produced by the player are turned into digital signals and sent on to a synthesizer unit.

All these different synths can be connected up through MIDI to play other synthesizers. Synthesizers controlled through MIDI may even just look like a box, because there is no need for them to have keys at all.

Just amazing!

GIG OF THE CENTURY

IF YOU SAT DOWN AT THE LATEST SYNTHESIZER AND PLAYED EVERY SOUND IT COULD PRODUCE, YOU WOULD STILL BE THERE IN A HUNDRED YEARS' TIME.



Paul Raymond





Converting human waste into methane gas will be an essential part of tomorrow's farm. These huge silos store the raw material ready for conversion.

FUTURE FARMING

FARMS ARE CHANGING with the times. Today's farmers are likely to link their desktop computers along phone lines to the local weather centre for updates on temperature, wind and humidity levels, plus the latest short-term forecasts.

At the same time, automatic sensors in the fields send data about soil temperature and moisture content to be fed directly into, for example, a wheat-growing programme, to see if and when the irrigators should be switched on.

One area which is taking great strides is plant technology. It is a long and costly business growing and harvesting plants in the wild and then extracting the parts you need. Biotechnologists can now

take a plant and isolate the cells they want, and then grow them in a huge vat under controlled conditions. The soupy liquid in the vat is called a 'tissue culture'.

Success story

In Japan, a red dye called shikonin is used in cosmetics such as lipsticks. Traditionally the dye has been harvested from the roots of a five-year-old plant. But 1 kg of plants yields only 10 grams of dye, and so it was very expensive. Now one Japanese company makes the dye in tissue culture and can sell it 30 per cent cheaper than the current market price.

The most exciting project in this area concerns cotton. One American biologist has discovered a way to grow cotton fibres in the labora-

tory which is far more efficient than the conventional method. Billions of cells are wasted as leaves, stems and roots in the cotton plant, but only the cotton fibres are wanted.

Safe and speedy

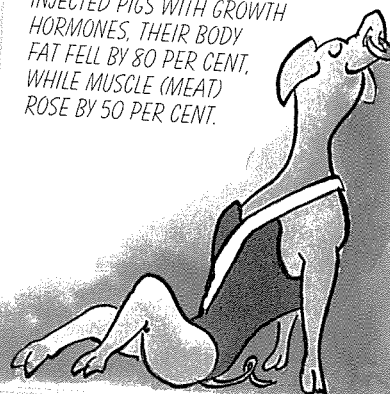
In the test tube, every cell becomes a fibre, and the whole process takes only half the time. Other benefits are that the cotton is free of the bugs that cause 'brown-lung' disease in textile workers, and fibres can be grown to a specific strength

Pascal Nieto/Jerrican

Just amazing!

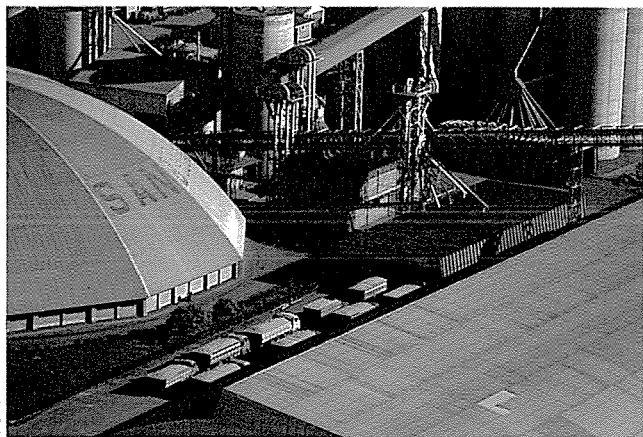
LEAN BACON

AN AMERICAN SCIENTIST HAS DEVELOPED A LOW-FAT PIG. WHEN HE INJECTED PIGS WITH GROWTH HORMONES, THEIR BODY FAT FELL BY 80 PER CENT, WHILE MUSCLE (MEAT) ROSE BY 50 PER CENT.



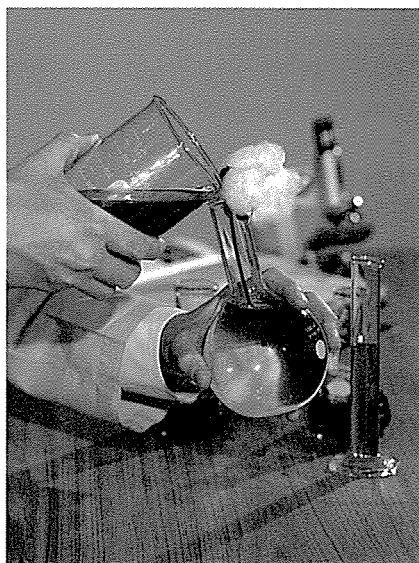
Paul Raymonde





Soybeans are big business. At this giant factory in Brazil, trucks unload huge quantities of beans for processing into soya oil and flour.

Seeds can now be planted in long biodegradable 'carpets', which are laid in the fields. There, they break down and the seeds grow normally.



Test tube cotton is an exciting example of biotechnology. Every cell becomes a cotton fibre and the process is far quicker than traditional cotton growing.

and length, as required.

Versatile soya

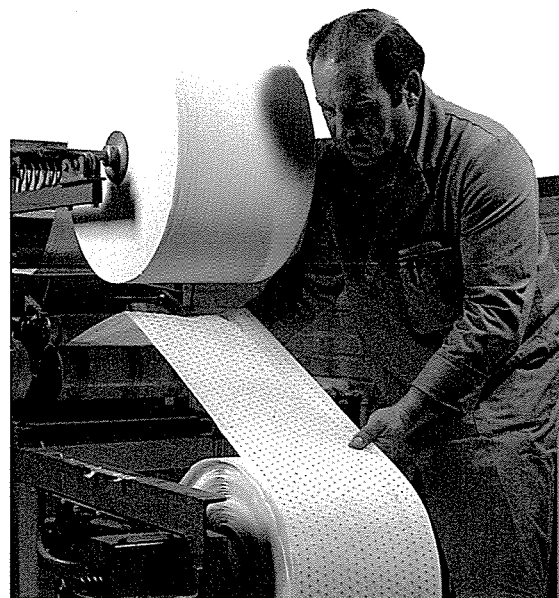
The soya bean, or soybean, is the most important pulse crop in the world. (Pulses are peas, beans, lentils and similar plants.) Soybeans are high in nutrients, and could become the crop of the future.

Soybeans are pressed for their oil, which is low in the type of fats that contribute to heart disease. The beans can be ground into a flour, while the fibrous part can be 'spun' and flavoured to make meat substitutes. They are also used as animal feed and in industry to make plastics, artificial rubbers, soaps, paints and inks. Fermenting the beans with fungus has even produced a contraceptive drug.

Jojoba

Before the ban on commercial whaling, the sperm whale's oil had been used for years to make shampoos and cosmetics. But biochemists showed that oil from the jojoba plant, a shrub from the Sonora de-

sert in Mexico, could do the job nearly as well. Now over 200 square km in the south-west of the USA are growing jojoba. The oil pressed out of the seeds is bought by cosmetic companies. But what about the 'meal' that remains? Some of its protein could be extracted and used

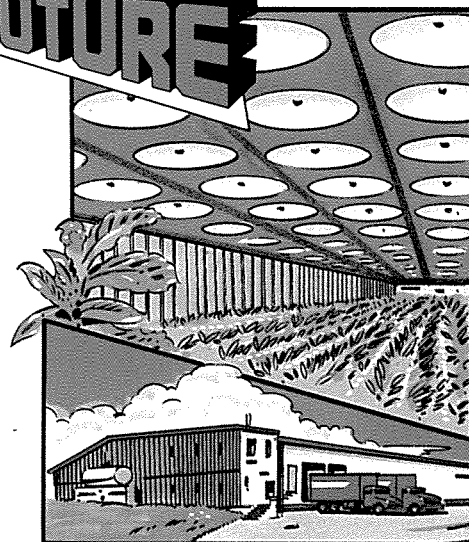


to feed farm animals. Other parts have applications in the paper industry. Blocks of meal can serve as fuel for fires.

Waste-free buffalo gourds grow in dry regions of North America. The stems and leaves can be eaten by livestock. The huge roots contain starch, which can be used in cooking or changed into sugars. The seeds are rich in protein and oil, and when the oil has been extracted, the leftover meal can be fed to animals.

INTO THE FUTURE

THE AUTOMATED FARM



▲ The farm of the future may be indoors, with genetically engineered plants growing in perfect conditions all year round. Light, heat and humidity would be computer-controlled

▲ The whole process, from planting seeds to packing the harvested crops, would take place on huge conveyor belts, moving around the farm very slowly.

▲ Automation could mean that farmers need never get their hands dirty, but just monitor the computers and replenish supplies for the feeding systems.

PROGRAMMED FOR HEALTH

-  DESK-TOP DOCTOR
-  ROBOT SURGERY
-  BODY IMAGING

THE EXPERT DOCTOR SYSTEM is the electronic doctor of the future. It can ask you how you feel, diagnose your illness and tell you which medicine to take – all on a small computer screen.

Although it may never replace the family doctor, the computer has an important part to play in medicine of the future. Although these 'expert doctor systems' have to be developed on large machines, they can be used on small, personal computers in the home or in the doctor's waiting room.

'Interviewing' of patients by computer can save a great deal of the doctor's time. Instead of the doctor quizzing the patient, the patient can 'talk' to the computer, which then makes a diagnosis and suggests an appropriate treatment.

VDU confession

When the idea of interviewing patients by computer was first put forward, it was thought that some people wouldn't want to co-operate with a computer and would be put off by it. In fact, many people actually prefer the computer to the doctor! Alcoholics, for example, tell the computer they drink more than they will admit to their doctor.

Robots are being developed to



Hank Morgan/Rainbow

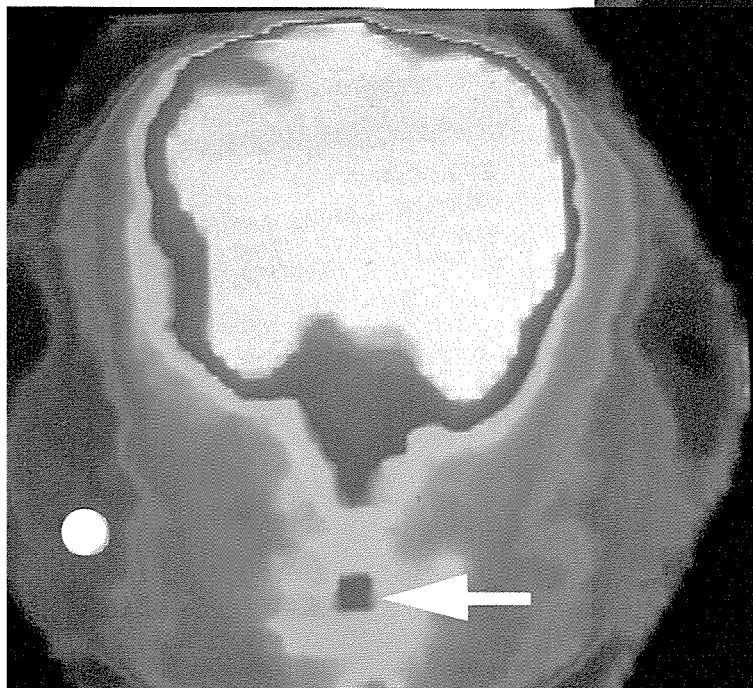
SQUID imaging systems are so sensitive they can detect the brain's magnetic field from outside the skull. This painless process gives a 3-D image of the brain for analysis.

A tiny tumour in the ovary, picked up by a gamma-ray camera. Radioactive substances called tracers injected into the patient, are carried around the body by the bloodstream, and 'brand' the tumour as a red spot in the on-screen image (arrowed).

help in delicate operations. These robots must not only be 'intelligent', they must also be precise. A robot connected to a scanning system will be able to locate a tumour very accurately and guide the surgeon to exactly the right place. This very accurate 'keyhole surgery' means that damage to surrounding tissue will be reduced, and the patient will only carry as small a scar as possible.

Radiation beam

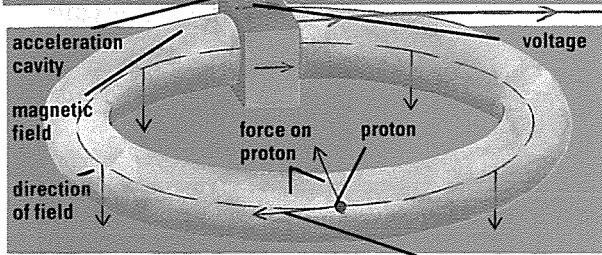
At present, cancer is treated using drugs, radiation, surgery and lasers – with some success. Much interest is now being directed towards proton beams as a form of cancer therapy. Protons are electrically charged particles present in the nuclei of atoms. They are used as a safe alternative to large doses of radiation therapy.



Gamma/Frank Spooner Pictures



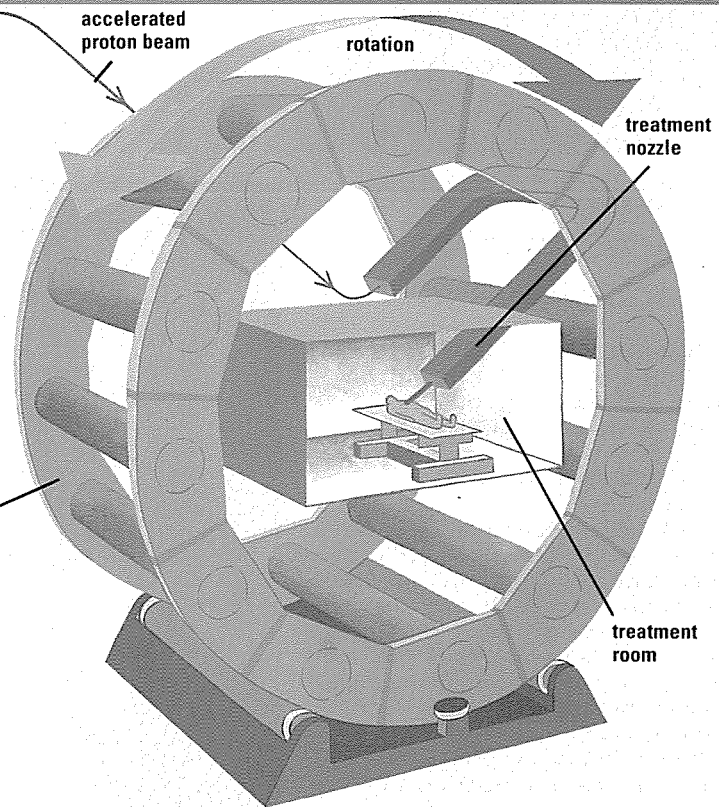
BLASTING TUMOURS WITH HIGH-SPEED PROTONS



Proton accelerators – vast machines that create fast-moving streams of protons (electrically charged sub-atomic particles) – are at the forefront of cancer therapy. The patient lies inside an enormous Ferris wheel that can direct the nozzle of the proton accelerator at any point on the body. The nozzle is only the very end of the accelerator system (above). Powerful super-magnets create an intense magnetic field that drives the protons faster and faster until they reach a critical speed, when they are diverted out of the acceleration tube down the beam line into the nozzle. Under the concentrated proton beam, the tumour breaks up and is excreted from the body. The depth of the beam into the body can be varied to within a few millimeters.

velocity of proton

rotatable framework



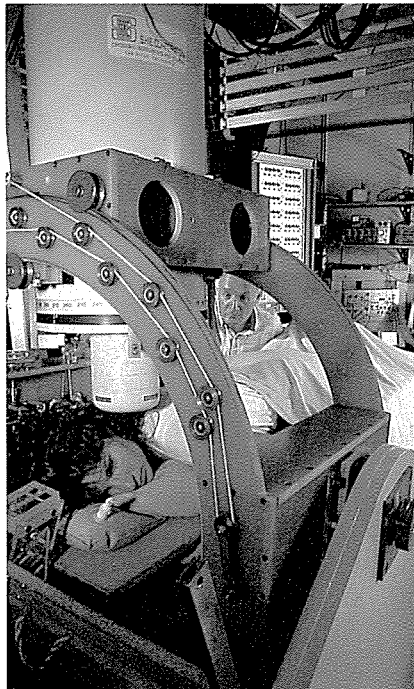
Caroline Brodie

Normal radiation therapy – bathing the tumour in radiation from a radioisotope to break it down – has the side-effect of damaging healthy tissue around the tumour. The advantage of using protons is that they can be sharply focussed to deliver the maximum dose of radiation to the tumour, while not harming tissue in front of or behind it.

Mapping the body

Machines known as MRIs or Magnetic Resonance Imaging systems make electronic 'maps' of internal areas of the body. This technique is very useful in detecting otherwise unseen diseases. A disease called osteoporosis, in which the bones

MEDICL is a computer system designed to help doctors with accurate diagnosis.



Five SQUIDS are incorporated within a single cylinder in this model, which surrounds patients with hi-tech machinery.

The patient lies in a darkened chamber with a SQUID helmet on. He sees bright flashes of light when that part of the brain dealing with vision is stimulated, or hears a high-pitched tone when the brain's auditory receptors are stimulated. This can be very useful in neurology, the study of the body's nervous system. If the optic nerve is stimulated, but the patient does not see a flash of light, then the brain's visual centre may be damaged.

become brittle and break very easily, is difficult to diagnose without imaging systems.

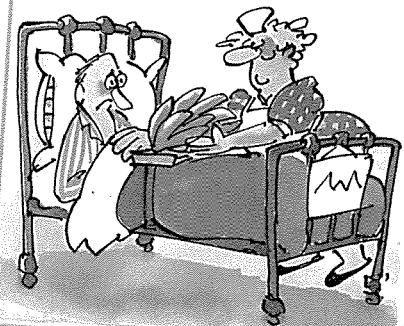
Quantum leap

However, newer and more advanced machines for imaging are being developed. These machines, called Super-conducting Quantum Interference Devices, or SQUIDS, are used to map the brain's electrical activity. They work by stimulating various areas of the brain and measuring the brain's electrical response.

Just amazing!

BANANA SPLIT

UNRIPE, GREEN BANANAS HAVE BEEN FOUND TO CONTAIN A SUBSTANCE THAT CAN BE USED TO CURE STOMACH ULCERS.



Paul Raymond

James Prince/SPL



- NUCLEAR COLLISION
- SUPER COOLING
- BRAIN POWER

FORECASTING THE WEATHER is a very complex task. So is mapping the air flow around the body of a new car or modelling the sudden explosion of a giant star.

To do any of these tasks, you need one of the new generation of supercomputers which can perform up to 16 billion calculations a second.



Weather models

At the European Centre for Medium-Range Weather Forecasts in Reading, Berkshire, UK, a £20 million Cray Y-MP C90/16 supercomputer is fed daily with vast amounts of information gathered by orbiting satellites, balloon-borne instruments and ground equipment. The Cray feeds all this data into a detailed mathematical 'model' of how weather systems operate and comes up with a global forecast for up to ten days ahead. If you tried to make such forecasts with an ordinary computer it would be hopelessly out of date before it could ever be announced!



Air resistance

Other supercomputers have been put to work by automobile and aircraft manufacturers. In the past, the only way to determine the air resistance, or drag, of a new car was to run a number of tests on various different models and prototypes in a wind tunnel. This was both expensive and time-consuming. But now, companies such as General Motors in the

Even before a prototype has been built, the Cray supercomputer models the flow of air around the body of a new car at General Motors.

SUPER COMPUTERS



David Parker/SPL

The Cray YMP Space C90/16 Super Computer has 16 powerful central processing units, each of which can perform 1000 million calculations per second.

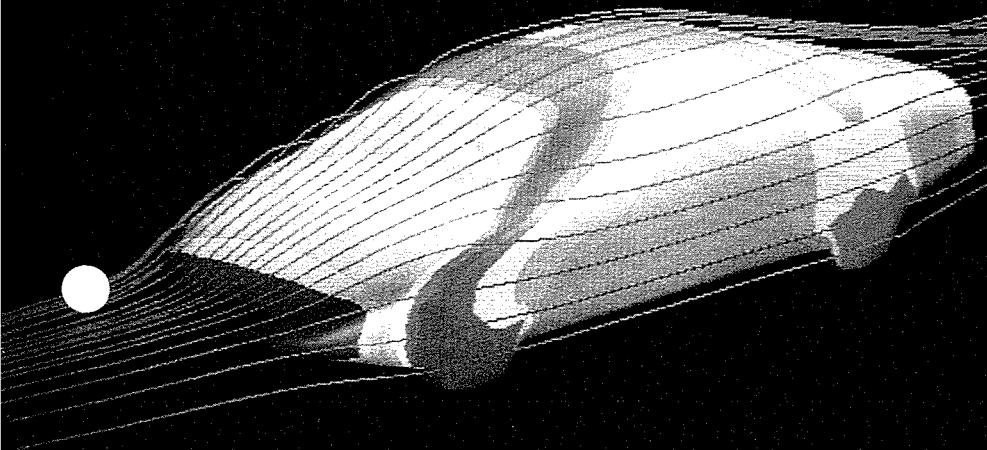
United States, Mazda in Japan, and Jaguar in Britain have enlisted the aid of supercomputers in their car designs.

Super sifter

The supercomputer simulates what happens in a real wind tunnel by sifting through countless equations and a mountain of data.

The same computer can also reveal ways to make an engine run more efficiently so that it burns less fuel or gives off less pollution. It can even show what would happen if a

Hank Morgan/SPL



car crashed into a wall at, say, 40 or 60 kilometres an hour.

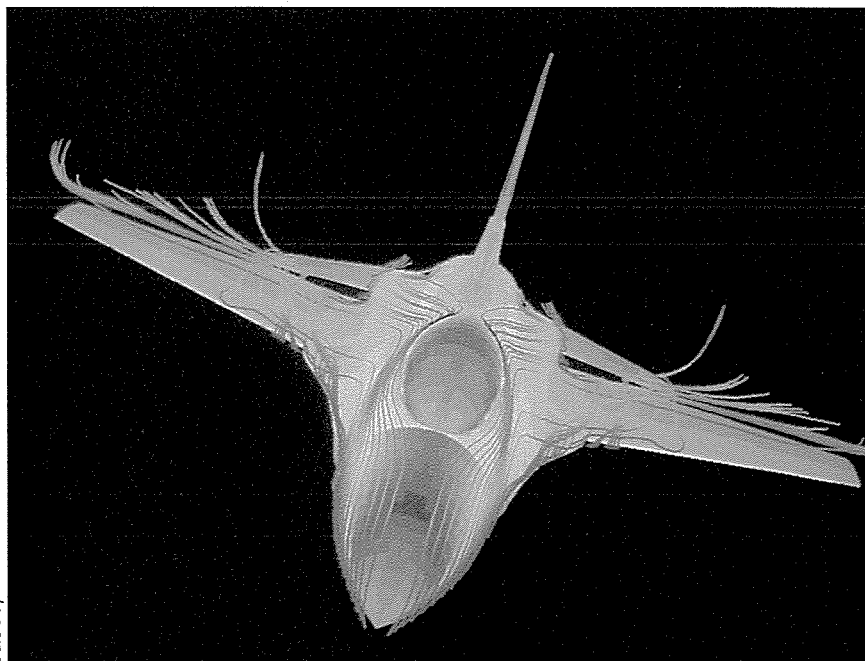
By analysing the results, engineers may then be able to improve the safety of the design while still retaining a lightweight structure.

Atom smashers

At the Lawrence Livermore National Laboratory in California, USA, a supercomputer allows scientists to smash together imaginary nuclei. During such an experiment, researchers tell the computer to take several 'snapshots' of what is going on. Each snapshot shows a stage in the impact between two nuclei travelling at speeds approaching that of light.

Represented as brightly coloured droplets on a screen, the nuclei come together, wobble and stretch, and then either break apart again or stick together. By studying these pictures, the Livermore researchers hope to understand better the results of their actual experiments with nuclear collisions.

Dale Boyer/NASA/SPL

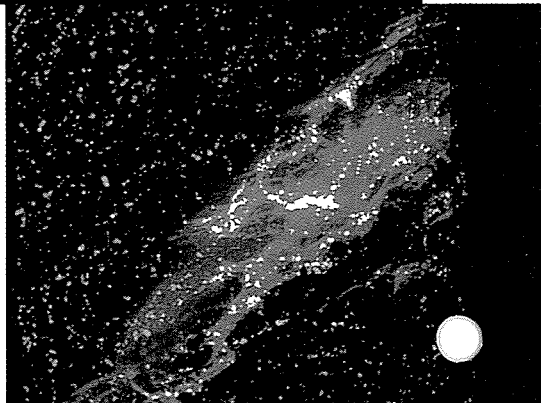


The airflow around the proposed design for the F-16 jet fighter was simulated without the expense of having to build several models and test them in a wind tunnel.

The Universe's secrets

At other labs, too, much basic research is being carried out with the aid of these giant computer systems. In discovering how galaxies form, how the chemical processes within our own bodies take place, and even how the next generation of high-speed computers may be built, today's supercomputers have a vital part to play.

Supercomputers are also used to test theories of how galaxies form. The supercomputer's predictions can then be compared with what we see in the sky.



Hurricanes are tracked and their likely course predicted (inset below) by supercomputers at weather research centres. This way people in the path of a hurricane can be warned.

that without proper cooling the entire computer would melt down within minutes!

To avoid this, 900 litres of a special liquid, known as fluorinert, are pumped continuously over and around the CRAY's circuit boards.

In the future, even more exotic ideas in supercomputer design seem certain to emerge.

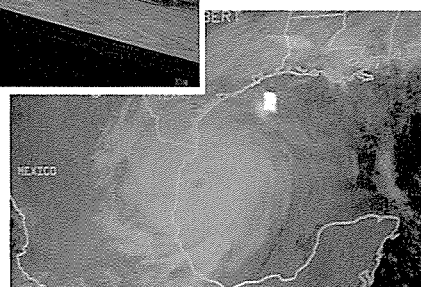
Dr John R Dickel/SPL



Gamma/Frank Spooner Pictures

Costly though they may seem, supercomputers quickly prove their worth. Within months of its installation, a supercomputer at the American ARCO Oil and Gas Company helped find ways to pump out five per cent more oil from the huge Prudhoe Bay field off Alaska's coast. The total value of this oilfield has been estimated at over \$100 billion. Five per cent of this colossal sum is \$5 billion – money that ARCO might otherwise not have earned.

Already, in the race to build the world's fastest machine, supercom-



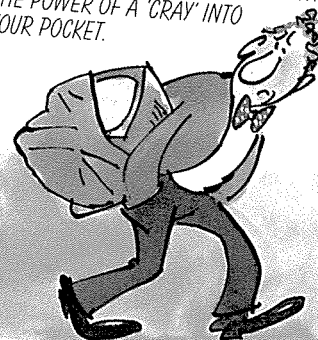
Gamma/Frank Spooner Pictures

puter designers have come up with some amazing schemes. Among the strangest is the cooling system devised to carry away waste heat from the CRAY-2 computer. The electronic components of the CRAY-2 are so densely packed, and give off so much heat,

Just amazing!

POCKET-SIZED

AS THE MINIATURIZATION OF CHIPS CONTINUES, COMPUTERS WILL GET SMALLER AND SMALLER. YOU SHOULD BE ABLE TO PUT A SUPERCOMPUTER WITH THE POWER OF A 'CRAY' INTO YOUR POCKET.



Paul Raymond



THE FIFTH GENERATION

- Q SUPERCONDUCTORS
- Q OPTICAL FIBRES
- Q NEURAL COMPUTERS

COMPUTERS OF THE FUTURE the fifth generation, will be totally unlike any in use today. Some will be built from superconductors through which electricity can pass without resistance at ultra-high-speed. Others will calculate using beams of pure light. And still others will be wired up in the same way as a human brain.

Today, almost all computers are constructed from silicon chips. Each chip contains thousands of transistors that act as tiny switches in the computer's processing, section and memory. One way to make a computer faster is to cram more transistors on to a single chip. But as that becomes increasingly difficult, scientists are turning to other methods of boosting the computer's power.

Electricity travels relatively slowly through silicon. However, chips made from a substance called gallium arsenide allow current to pass through five times as fast. Already, a few supercomputers are being built from this new material.

Supercool

When some substances are cooled down close to absolute zero (the coldest temperature possible), they become superconductors. In this state, they let an electric current pass through them with virtually no energy loss.

Switches based on these supercooled superconductors, known as Josephson junctions, have been

In the film 2010, a man enters the central processor of a computer guilty of murder, to destroy its decision-making ability. One day, computers may reason so like humans and be so powerful that they could be capable of criminal behaviour.

MGM



tested in the laboratory. Incredibly, they can flip on and off trillions of times a second — much faster than any conventional switch. Yet there are big problems still to be overcome in working with a computer that runs at such a low temperature.

Those problems may disappear if one day there is discovered a new class of substances that behave as superconductors at room temperature. A computer based on these would need no special cooling and yet could run at high speed

be built to handle the switching of several incoming signals at once. Beams of light can criss-cross and overlap without any risk of them becoming mixed up, whereas crossed electric currents would get hopelessly confused.

Optical computers would have other advantages, too. Many instructions or pieces of data could be sent through such a computer along the same optical fibre.

A computer working with light could be linked directly to a future phone network of optical fibres. There would be no need for any

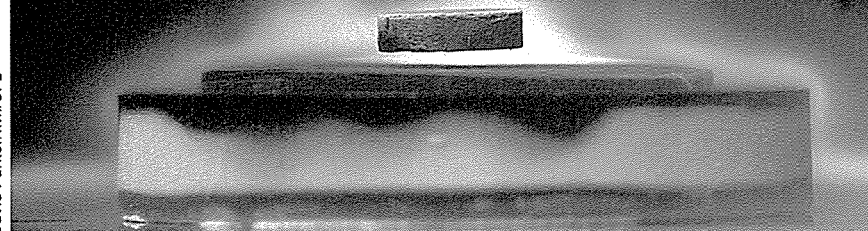
BIOCHIPS



Dr Arthur Lesk/SPL

The basis for a computer built on the lines of the human brain could be the biochip. Constructed on the basis of protein molecules (such as the one shown in the computer graphic image above) and specially designed for the task, biochips could be made to work like a complicated switch. Since they would be built of living material, networks of biochips might be able to organize themselves in different ways or even repair themselves if damaged.

A ceramic superconductor allows electricity to flow through it with no resistance. Liquid nitrogen, (the glowing vapour) keeps it at the right temperature. A magnet, repelled by the superconductor, floats above.



David Parker/IM/SPL

using virtually no power. However, the highest superconducting temperature so far achieved is -146.3°C . This was attained under strictly controlled laboratory conditions for a short period of time. So far no method has been found by which superconductors may be produced in a commercially viable form.

Today, tiny bright flashes of laser light can be sent hundreds of kilometres along fine strands of specially made glass, called optical fibres. In the future, these fibres will be used to replace ordinary wires in a revolutionary new type of computer — the optical computer. In place of transistors, such a computer will have transphasors — switches that work using pulses of light instead of electricity.



The power of light

Experimental transphasors have already been made to flip on and off a thousand times faster than any present-day switch. And, unlike a transistor, transphasors can

special equipment to change electrical signals to light signals and back again.

The most sophisticated computer ever made is inside your head. You may not be able to add or multiply as fast as a man-made computer, but you can imagine, create, understand and think in other ways far better than the most powerful supercomputer on Earth. If human brains are so good at abstract thought, why not build computers in the future that mimic the way our own brains work?



The human brain

Right now, teams of scientists around the world are pursuing that very goal. Their hope is to design so-called neural computers, whose switches are linked together in much the same way as human brain cells are. The task is enormous. An

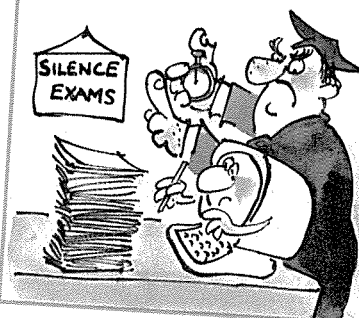
adult brain contains up to 100 billion cells, or neurons, each of which connects to about 10,000 of its neighbours. What is more, unlike an ordinary computer that does one calculation after another, all of our brain cells work together in parallel. Parallel working — doing several jobs at the same time — is the most important way to improve computers.

Optical fibres are fine strands of glass through which tiny, bright flashes of light send information. They will replace electric cables in computers of the future. The fibres can be twisted, coiled and bent.

Just amazing!

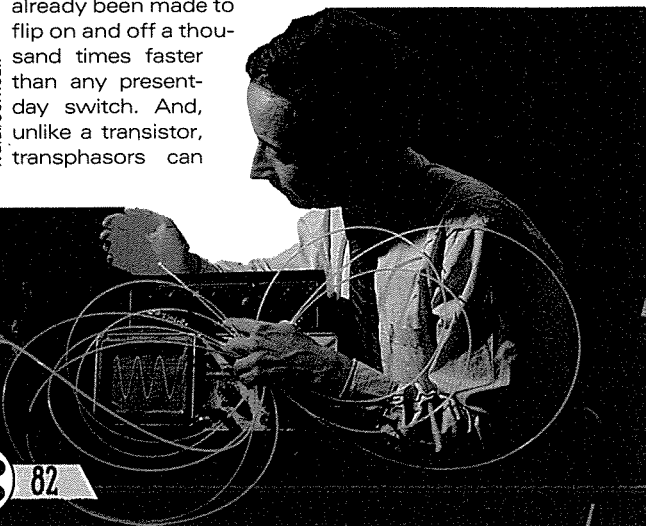
FAST WORKER

THE NEW INTEL 860 'SUPERCHIP' CAN DO AN ASTOUNDING 150 MILLION OPERATIONS IN JUST 1 SECOND — OR 9000 MILLION PER MINUTE.



Paul Raymond

Ivaldi/Jerrican



UNDER SURVEILLANCE

-  ELECTRONIC TAGGING
-  TELEPHONE TAPPING
-  VOICE PRINTS

system naturalists have been using for years to track animals and study their behaviour.

Currently, electronic tagging is being used in the United States on prisoners on remand — that is, people who have been arrested and charged with a crime, but not yet tried or convicted. Their movements are monitored so that they cannot leave their home State undetected. If they try to remove the tag, the police are alerted immediately and they will be taken back into custody.

Catching criminals

There are plans to extend this scheme to convicted criminals. Their movements can be restricted to their own home and their workplace. If they went anywhere else the tagging system would immediately alert the police. A curfew could be applied so that the convicted criminal would have to be at home at certain times.

Electronic surveillance is also

No conversation is safe from the eavesdropper. Under the table (inset) there is a bug — a tiny microphone and radio transmitter.

prisons where their movements are restricted so that they can be watched 24 hours a day.

The problem is that prisons are overcrowded. New ones are very expensive to build. Also, prisons can be 'breeding grounds' for crime, allowing young criminals to learn from older ones. Prisoners take people away from their families, causing social problems. Prisoners rarely have the opportunity to work and earn their keep — so they get out of the habit of working, making them more likely to turn to crime again when they get out.

No escape

One way around these problems is not to send people to prison, but to keep a check on them round the clock in the community. In some countries electronic tagging is now being used to do just that. A small radio transmitter, attached to the person, sends out a specially coded transmission that can be constantly monitored. Essentially it is the same

ALL GOVERNMENTS LIKE TO keep an eye on their citizens. They like to watch criminals, spies and some even keep people who simply disagree with government policy under surveillance. Modern electronics can greatly help security men to keep watch on any individuals they consider a threat.

No-one much objects to the government keeping an eye on criminals — especially those that have already been convicted and sentenced. Usually criminals are put in

Just amazing!

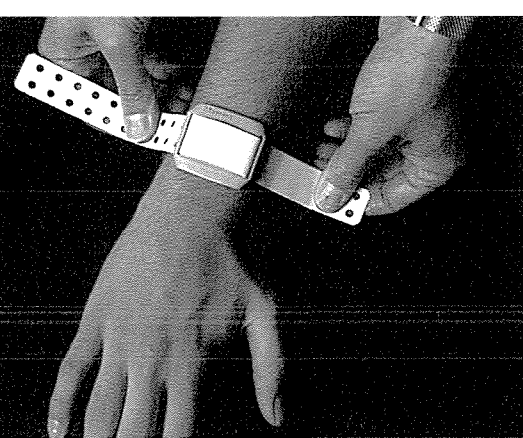
LIGHT BUGS

IT IS NOW NOT NECESSARY TO PLACE A BUG IN A ROOM. WHEN SOUND HITS A WINDOW PANE, THE GLASS VIBRATES SLIGHTLY AND LASER LIGHT REFLECTED FROM OUTSIDE THE WINDOW CAN PICK UP WORDS.



Paul Raymond





Derma/Jefferies/SPL

Electronic tags fit around the wrist or ankle. They cannot be removed without the police being alerted.

used to catch criminals. Like everyone else in the modern world, criminals are heavily reliant on telecommunications. So police forces and governments around the world eavesdrop on telephone conversations and other forms of electronic data transmission.

The most frequently applied technique is the telephone 'tap'. When a telephone is tapped, it means that all calls on that number are intercepted and conversations are recorded without the knowledge of the people talking.

Target lines

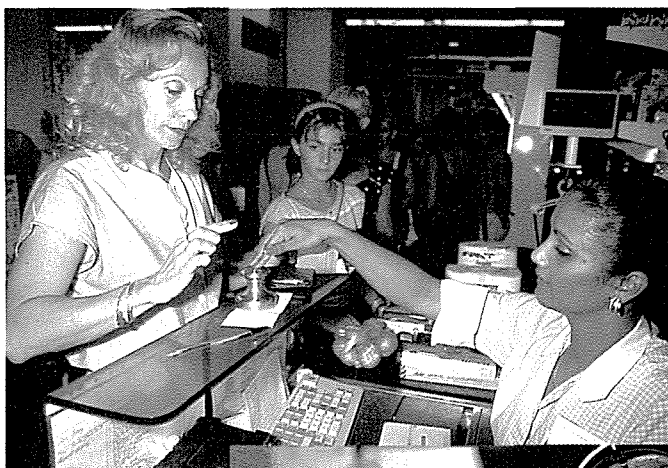
The tap is made by adding an 'extension' to a particular line at the telephone exchange – and this is activated whenever the target line is used. Targets for telephone tapping include people planning serious crimes, drug pushers, spies and organizations which the government considers 'subversive'.

Electronic surveillance does not stop at individuals. Throughout recorded history, governments have spied on one another. Today, most spying is done by monitoring the communications systems of foreign

countries. Not only does this give an insight into matters of policy but, perhaps more importantly, information on trading activities. As trade is the life-blood of the Western world, such 'economic intelligence' is of vital importance.

Commercial communications passing through the world's satel-

Fingerprinting is used in some countries to stop bad cheques. The shop stamps two spots on the back of the cheque. The customer presses her finger on the yellow, then the red spot, leaving a 'signature' print – but not staining her finger.



Gamma/Frank Spooner Pictures

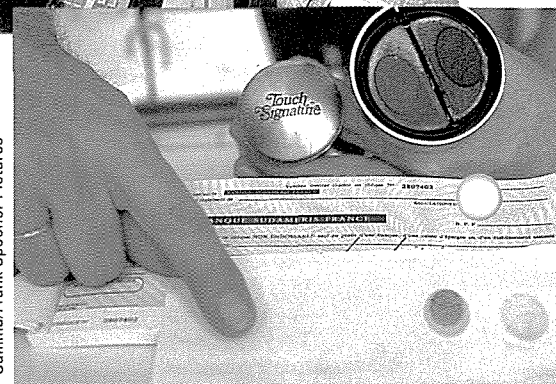
lite telephone system, diplomatic traffic between embassies and their home countries as well as internal communications within 'countries of interest' are all monitored.

It is possible to do this because most communications systems rely at some stage on a radio link. The physical nature of radio waves means an eavesdropper cannot be prevented from picking them up.

Secret establishments need to prevent access to unauthorized

people. Two ways of doing this are the use of voice and fingerprint recognition systems. Like fingerprints, a person's voice is completely unique and can be used to identify authorized individuals.

Of the two, voice recognition is the more difficult to achieve. To work, such a system needs to be programmed to recognize a particular voice. The computer can compare this 'voice print' to the voice of someone wanting to enter the secret establishment.



Gamma/Frank Spooner Pictures

INTO THE FUTURE

TOMORROW'S JOURNEY



▲ Open borders will one day make entering another country much quicker – traditional passport control will be a thing of the past.

▲ Instead of a passport, travellers will have a 'smart card' confirming identity and providing a central computer with health and other important information.



▲ The central control system will immediately register any undesirable aliens – criminals or terrorists – and secretly tip off security men.

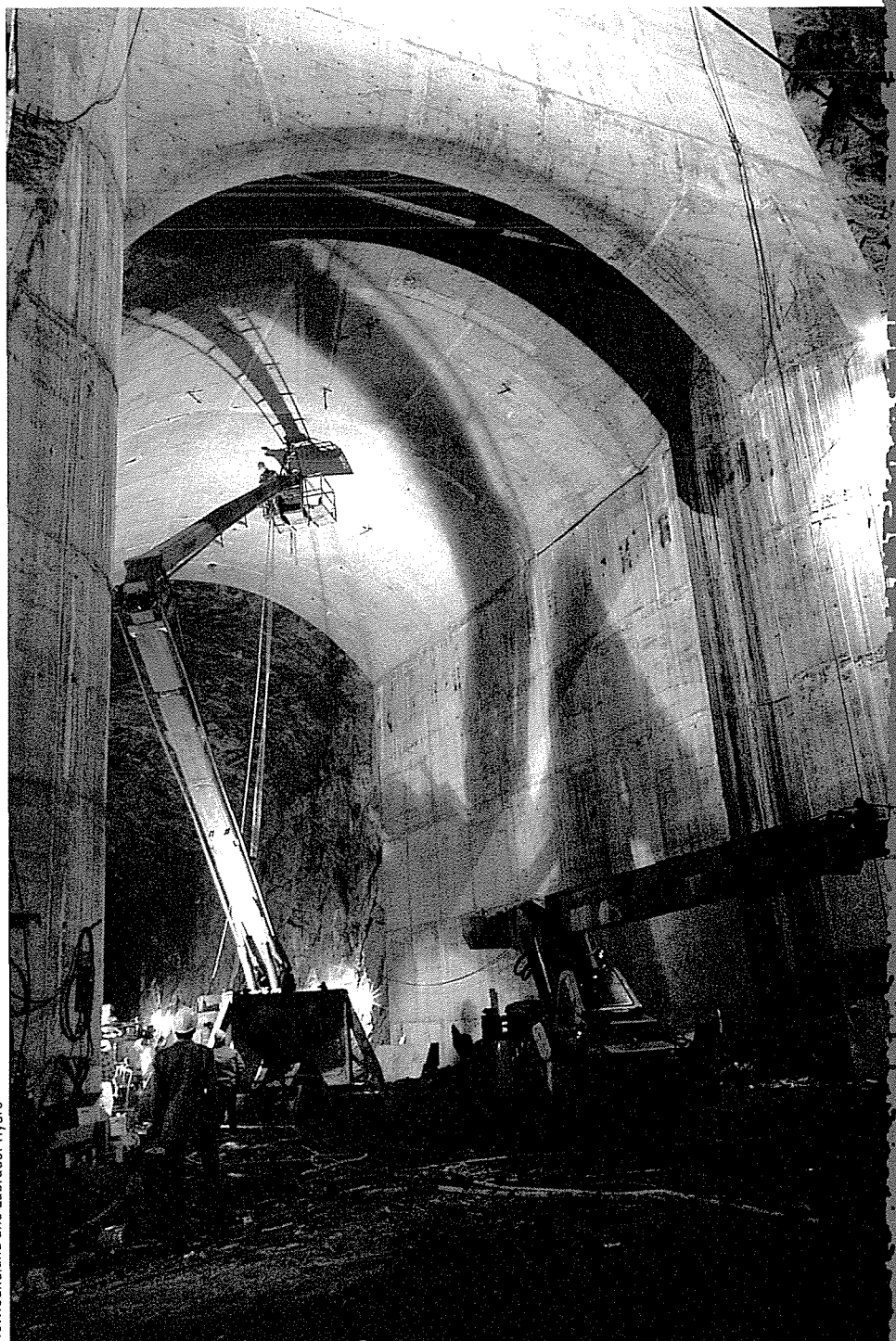
DOWN TOWN

- Q EARTHSCRAPERS
- Q NUCLEAR PROTECTION
- Q SINKING CITIES

AS POPULATION GROWTH forces cities to find ever greater amounts of accommodation for their citizens, planners must look either outwards, upwards or downwards.

Spreading outwards, beyond the city limits, destroys one of the few remaining 'free resources' that the planet possesses — the countryside. Spreading upwards not only destroys the skyline, leaving unnatural and, some would say, oppressive views to city inhabitants, but social research has shown that high-rise living is unduly stressful, tending to isolate people from their neighbours and encouraging vandalism and violent crime. Many planners are, therefore, beginning to look beneath their feet.

•One way of building underground



Newfoundland and Labrador Hydro

The powerhouse floor of the Churchill Falls plant, Canada, 253 metres underground.

Constructing the surge chamber of the Churchill Falls hydro electric plant.

is known as 'earth-sheltered' construction. A house is built in an excavation, then covered with a layer of soil. Not only do such buildings blend inconspicuously into the surrounding countryside but fuel bills can be greatly reduced due to the insulating properties of the earth. At present, this is the main type of underground housing, with more than 10,000 houses in the USA and over 4 million in China.

One of the best examples of earth-sheltered technology is the

Terraset Elementary school in Virginia, USA. Built in the mid-1970s, the school buildings, which cover an area of 7,000 square metres, were overlaid with a 60–90 cm layer of earth. The entrances were 'counter-sunk' and the covering earth was made into outdoor play and recreation areas.

Clean air

Another type of construction is the semi-subterranean building. This has proved popular for many large municipal buildings, such as multi-storey car parks. The Law Library of the University of Michigan has all its three storeys underground; the Smithsonian Institution Museum Complex in Washington DC is 96



per cent underground; and the Civil and Marine Engineering building at the University of Minnesota is 95 per cent below the surface.

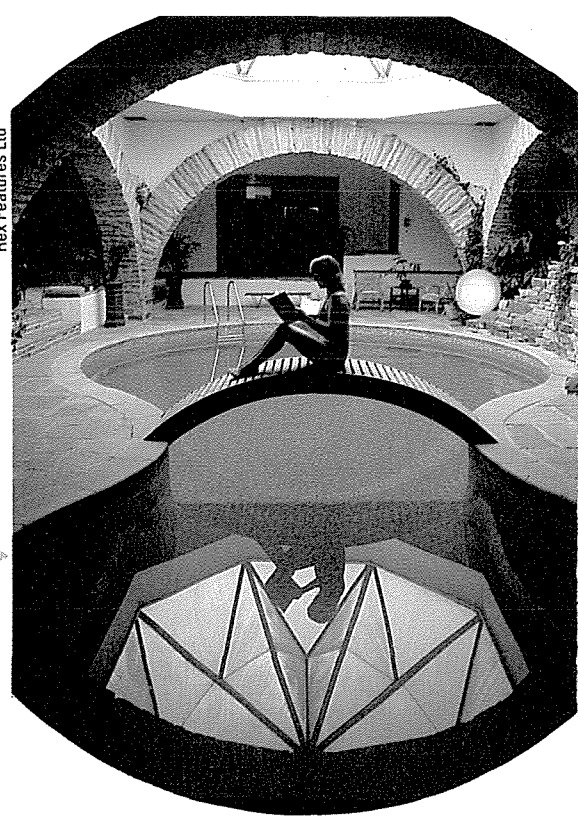
Subterranean buildings are ideal for science research and industrial complexes which need clean work environments, as few airborne pollutants find their way in.

Lastly, there is totally subterranean construction. Construction costs can be half that of conventional housing, particularly if an old mine, underground railway line or natural cavern can be altered to form a factory or trade complex. Similarly, as the temperature of most rock areas in warm countries remains fairly constant (at 7 to

10°C) to a depth of several thousand metres, heating costs can also be reduced.

Nuclear bomb shelters are, of course, built underground because a large thickness of earth and concrete is the best protection from nuclear blast and radioactive fallout. In Sweden, for example, where 80 per cent of the population can be sheltered, many public facilities, such as swimming pools and health centres, have been built underground so that they could be used

Underhill is a semi-subterranean, 4-bedroom house in the Peak District near Huddersfield, UK.

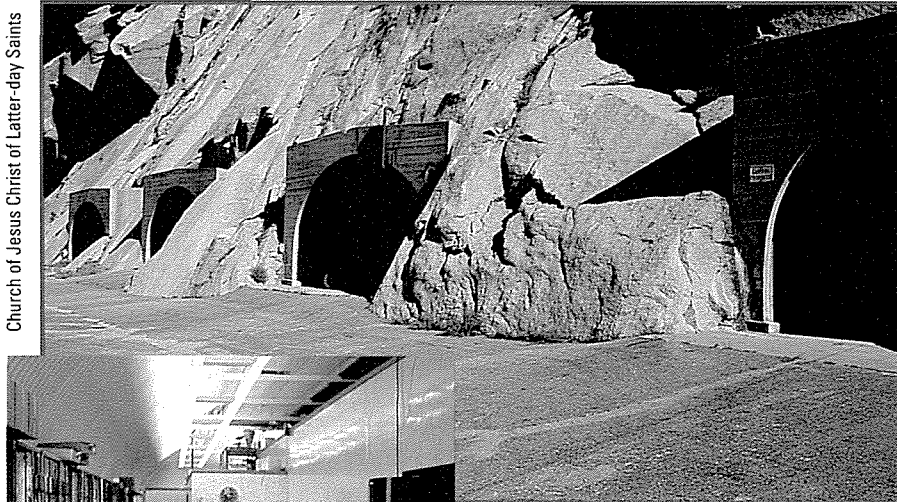


substation, but the importance of the development was to find out what it is like to try and build such an underground complex.

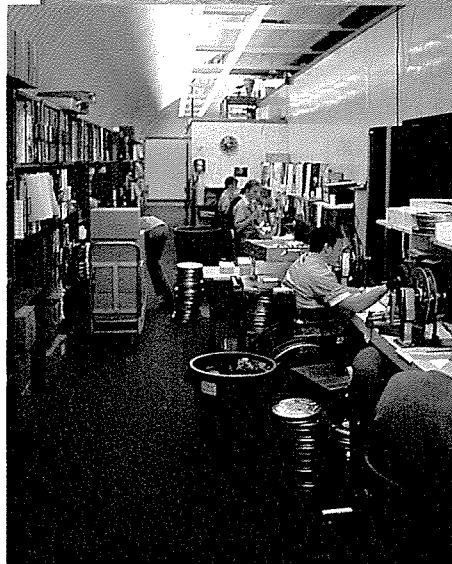
Earthquake-proof

One advantage of moving underground, particularly in areas like Japan, is that it reduces the risk of earthquake damage. Lined with flexible concrete and steel walls, the excavation 'rides' any shock waves caused by Earth tremors – the shaking recorded below the surface is less than one-third of that on the planet surface.

The current stumbling block is legal rather than technical. At present Japanese law states that land owners at the surface own the rights from the centre of the Earth to out into the Universe.



Church of Jesus Christ of Latter-day Saints



Church of Jesus Christ of Latter-day Saints

The Granite Vaults – ground level tunnels bored beneath the Wasatch Mountains in Utah, USA – are the storage facility for the Mormon Church's microfilm data of world members (left).

in the event of a nuclear war.

Similarly, key military facilities are normally built deep underground. The North American Air Defence Command (NORAD), for example, is virtually impregnable, having been constructed in caverns and tunnels deep inside Cheyenne Mountain at Colorado Springs.

Looking forward, the next step, some architects are predicting, will be 'earthscrapers' – inverted tower blocks that go underground instead of skywards.

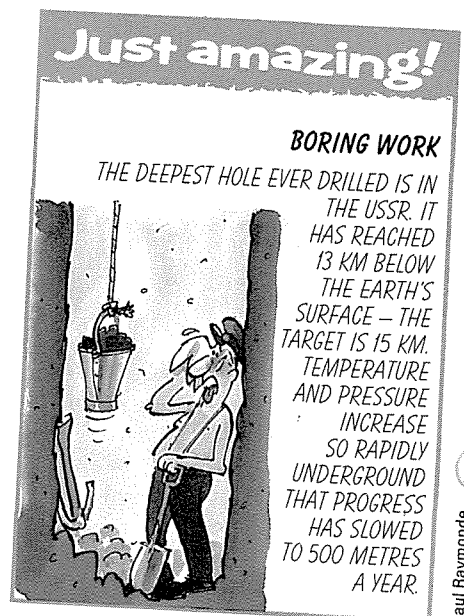
Geofrontier

With this in mind the Japanese Government launched the 'Geofrontier Project', at a cost of around £70 million, to develop techniques to build underground power stations, offices and even homes, more than 50 metres beneath the surface.

The project initially involved the creation of a large dome-shaped cavity, 50 metres wide and 30 metres high, with the floor 80 metres below the surface. The new cavern was designed to house a

IN ANOTHER WORLD

In 1989 Signorina Folini, a 27-year-old Italian researcher, spent four months in a specially built house some 10 metres below the earth's surface in New Mexico's Lost Cave. The purpose was to observe the psychological effects of isolation underground. She had no clocks, radios or external light source to give her a sense of time. The experiment showed that she fell into a routine of staying awake for 23 hours and then going to sleep for 10. The isolation also took its toll on her memory, concentration and reasoning ability. Stefania was underground for four months, but she thought she had been in isolation a month longer.



Paul Raymond



Computers will dominate the home of the future. From your central console, you will be able to control heat, lighting, and the home's electrical equipment.

DESIGNS FOR LIVING

- PRE-CAST HOUSES
- ENERGY SAVING
- COMPUTERIZATION

THE SHAPE OF TOMORROW'S homes will not be very different from today's. Apart from a few weird and wonderful designs from revolutionary architects, homes will take the same basic shape as they have done for many years.

However, the way houses are built may be revolutionized by different construction materials, especially plastics. Plastics come in many forms, and can be made cheaply and easily for almost any purpose. They can be made light yet strong enough to take heavy loads,

Modern architects have come up with some weird and wonderful homes. This design by Piet Bloom in Rotterdam harbour places houses above shops.

and transparent to admit heat and light but still insulate against the extremes of cold and heat.

The most widespread use of plastics will be factory-built wall panels and modules, which can be engineered by robots to accuracies of one-quarter of a millimetre. Already in Japan, 20 per cent of homes are assembled on site from ready-made steel and lightweight concrete panels.

Design-it-yourself

Home-owners can draw up their own design on a special computer program, which contains thousands of permutations. Within two weeks, panels or modules of lightweight steel and concrete are delivered to the site. They may even come complete with doors, windows and wiring, and can be assembled in a day, leaving just a week or two to finish the plumbing, electrics and painting.

Space technology

Plastics are not the only materials that could revolutionize building methods. In places that are ex-

Esto Photographics



tremely hot or cold, materials like the ceramic tiles used as heat shields on the Space Shuttle could be used for insulation.

One of the by-products of today's 'throw-away' society is waste from homes, farms and industry. One method of disposing of waste is to pour it into large trenches, then leave it to be compacted by gravity while bacteria convert it to methane gas and a solid 'cake'. This solid waste cake makes an excellent building material.

Energy-efficient

With so much emphasis on conservation of the Earth's resources, the efficient use of energy will be much more important in determining the size, shape, and location of future homes.

Architects in the USA have designed and built experimental homes in slopes and mounds so that the walls and roof are underground. When grassed over, the soil insulates against heat and cold and gives shelter from the wind. This makes it very energy efficient.

Underground heating

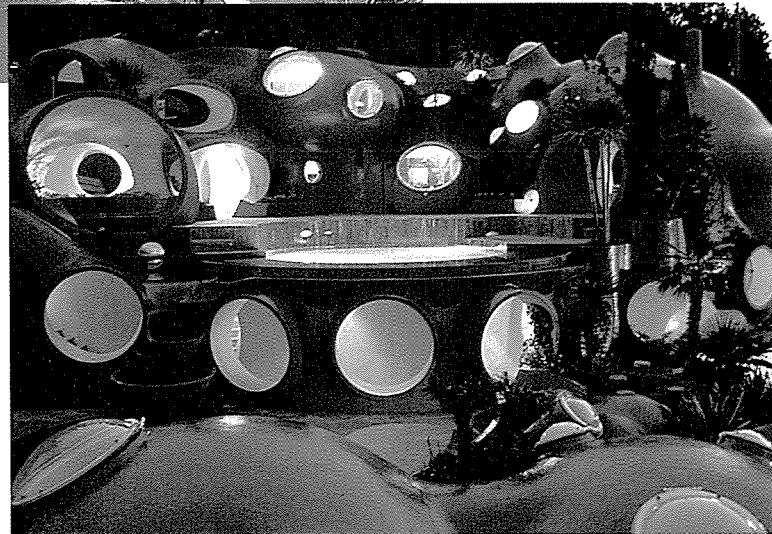
Because the temperature under the soil does not vary much in winter or summer, pipes from future central

A solar-oasis in the New Mexico desert. Water is pumped out of a well deep underground using the windmill on the right, and heated by the solar panels on the front side of the house.

Rex Features Ltd



A 'bubble house' in Cannes, France, designed by the radical architect Antti Lovag. He believes that right-angles are unnatural, so there are no angles in his house. The shapes are moulded out of concrete and plastic.



back into the house.

In the USA, over two million heat pumps are in use. In Sweden, the technique of soil insulation has been combined with low-cost heating by solar panels and heat pump central-heating.

A heat pump works like a refrigerator in reverse. While the refrigerator removes heat from within the compartment and dumps it outside, the heat pump takes warmth from the environment outside and dumps it inside. It can even extract heat from seemingly cold sources, such as a mass of rock or concrete or a reservoir of water in the foundations of a building.

Storage heaters

In summer, the heat pump can cool the interior by extracting the heat and storing it in the foundation.

Rex Features Ltd

Tom McHugh/Science Photo Library

heating systems will go under the ground in huge coils. In the winter, this will warm the heating water so that not so much energy is needed to heat it up. In summer, the cold water system can be routed through it, to cool the drinking water.

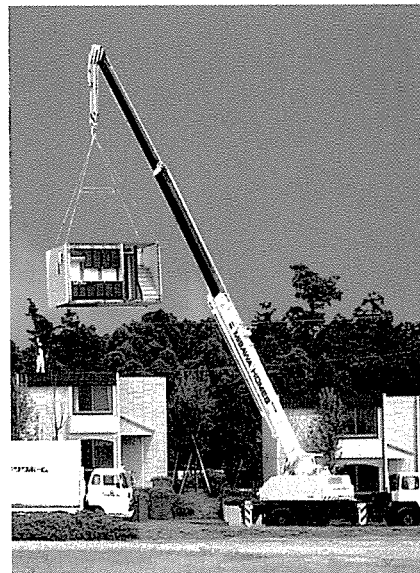
Solar energy

Solar panels will more frequently appear on the roofs of the houses of the future. Already they are being used to heat water in sunny parts of the world, but they can also be used in colder climates. Even in northerly countries, the sunshine can still provide valuable energy.

Heat energy normally wasted from

the home can also be recovered and re-used. Even tepid bathwater, for example, contains valuable heat, which can be passed through a heat exchanger into a storage system — a massive tank of water or rocks under the ground. When heat is needed, a heat pump can carry it

Mass-produced houses in Japan are pre-cast in concrete and steel panels on robotized assembly lines. Each module contains doors and windows and is wired and painted. Cranes put them in position, and they are assembled. One-fifth of all Japanese houses are so built.



Misawa Homes



COMBINED NETWORKS

Computing, broadcasting and telecommunications have traditionally been carried on their own, separate networks. But many countries are now looking at ways of carrying all these services together. They are setting up ISDNs – Integrated Services Digital Networks, which would be linked by a single, multi-core cable to each home. So television channels would come along the same cable as telephone and computer lines.

house is occupied and in which rooms the occupants are. By remote control, the computer will then be able to regulate the light, temperature and humidity in those rooms to suit sleeping, work or leisure.

By monitoring other electrical systems, the computer will easily be able to tell what is going on in a room at any time. On the simplest level, it will switch the lights on when someone enters a room, if they are needed, and switch them off when the room is unoccupied.

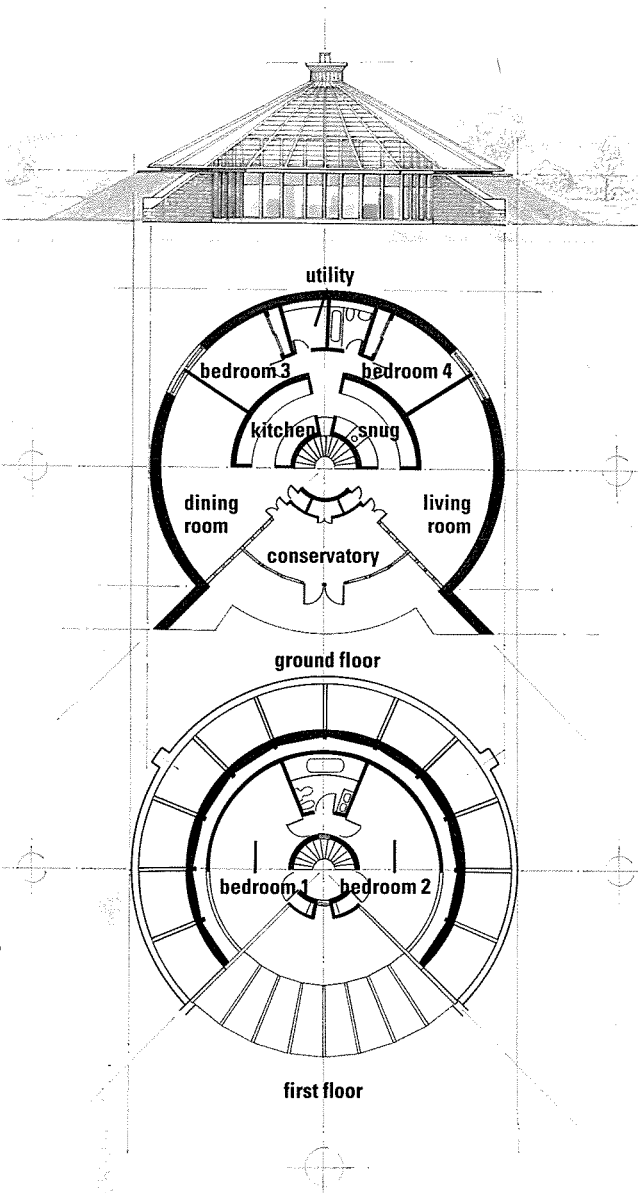
Waller/Jerrican/Science Photo Library

The Round House has been designed to be energy efficient. The earth banking around the sides helps insulate the living area, as does double glazing. Warm air can be extracted from the kitchen and bathroom and used elsewhere.

The 'media' room of a prototype home of the future in Dallas, Texas. One wall is filled with a bank of TV, computer and audio equipment. Computers (inset below) control heating, lighting, ventilation and security.



Waller/Jerrican/Science Photo Library



Keith Horn Architects/John Houghton

In winter, the cycle of the heat pump extracts heat from the foundation store and circulates it to warm the building. Such a system works best if it is automated and linked to suitable sensors, which makes it ideal for tomorrow's home.

'Home' computers

Like most other machines in the modern world, the home will also become computer-controlled. Separate television, telephone and home computing systems will be replaced by a single system under the central control of a master computer. This computer will be the heart of a network handling security, banking, telecommunications and entertainment systems.

A central computer will give people who work from home access to other computers, and will also control such everyday household functions as heating, lighting, ventilation and humidity. It will be important for security and safety, too.

Sensors

The computer will monitor the home continuously with a range of sensors, whether or not anyone is

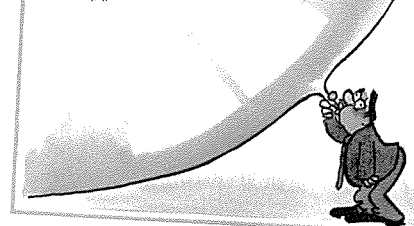
home. The retina of your eye is as individual as a fingerprint. A retina scanner at the front door will distinguish between members of the family and visitors so it can let them in, or refuse them entry, accordingly. It could also determine who is allowed access to each room. For example, young children could be prevented from going into the kitchen if no adults are present.

Using infra-red sensors that detect human body heat, the computer will be able to tell whether the

Just amazing!

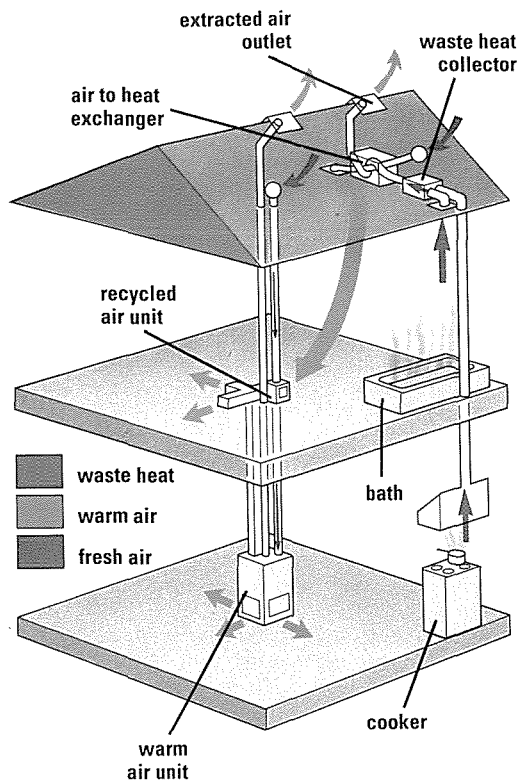
BUBBLES IN THE AIR

AN INFLUENTIAL ARCHITECT HAS PROPOSED BUILDING A HUGE BUBBLE IN NEW JERSEY – THREE TIMES THE HEIGHT OF THE EMPIRE STATE BUILDING AND 2½ KM WIDE – WHERE A MILLION PEOPLE COULD LIVE AND WORK.



Paul Raymond





Mark Franklin

Central heating systems are now being designed to re-distribute the warm air from cooking and bath water. An air-to-heat exchanger sends warm air back into a unit which mixes fresh, warm and recycled air.

Already there is an electronic unit that gives you complete control over your bath or shower. By programming its microprocessor, you can determine the exact temperature and rate of flow of the water. It will even switch itself off when the

bath is full and give an audible warning when it is ready.

The need for hygiene has changed the design of hand driers, taps and soap dispensers. Soon they will all be 'triggered' by breaking an infra-red beam as you put your hands underneath them.

Videophones

The television set and music centre, linked to the telephone and central computer, will become more than a means of entertainment. Already researchers in Japan have linked a video camera into such a system, so that viewers can transmit pictures and sound from their living rooms directly into a TV studio or to the homes of anyone they choose — giving them two-way communication by videophone.

A leading European electronics company has developed a hi-fi and TV system that can be networked around the whole house, and can be controlled from any room by either remote control units or touch sensors built into the walls. It allows you to choose a record, CD or TV programme and control it from any room in the house. You can even programme the unit to play music or switch on the TV days or even weeks ahead.

Multi-networking

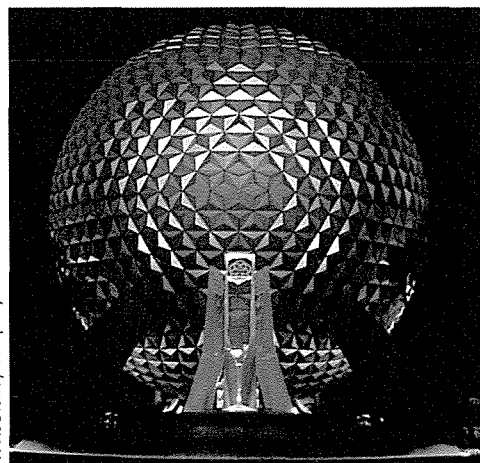
Transmitting video and computer signals within the telephone network is now possible. In many countries, telephone exchanges have been modernized so that they can handle vast numbers of signals at a fast enough rate to cope with computer data transmissions.

An important step was to replace

NEW SHAPE SHOPS

Geodesic domes are lightweight, strong, and spacious structures suitable for very large or very small dwellings. Developed by US architect, Buckminster Fuller in the 1950s, these spherical structures are assembled from simple shapes, such as triangular frames or flat planes.

Geodesic domes have been built as exhibition pavilions and shopping centres. They are simple and inexpensive to construct, and provide well-lit, spacious accommodation, without the need for internal supports.



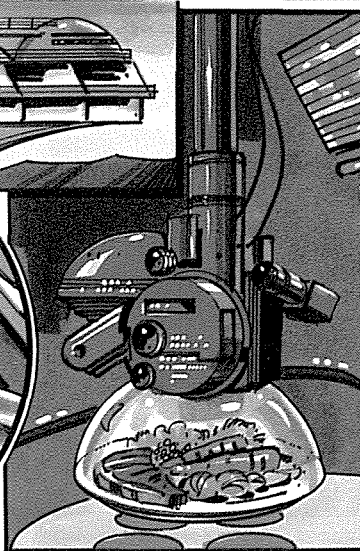
The Walt Disney Company

the old copper cables with fibre-optic cables so that the information could be sent digitally — as pulses. This has opened up the possibility of linking every home to just about any service. As a result, there would in theory be fewer reasons to go out — for example, all your shopping could be done from home.

INTO THE FUTURE



▲ The householder of the future will be able to telephone the central computer that runs the home and issue orders for the computer to carry out.



▲ He will be able to tell the computer to record his favourite TV programme, switch on the oven to cook a meal, start the washing machine and turn on the heating.



▲ When the householder returns, the computer will have taken care of everything. The house will be warm, a meal will be ready and the washing done.



HIT!

Tomahawk, the US Cruise missile (above), being tested on an exercise target with devastating effect. Capable of being launched from a submarine, surface ship, land mobile or from an aircraft, it can carry a high explosive or nuclear warhead.

THE PAYLOAD

DEALING DEATH FROM THE air, missiles come in many forms, from the Intercontinental Ballistic Missiles through Cruise missiles to anti-tank missiles. And there are variations of all of these. So what exactly is a missile?

Unlike a projectile fired from a gun or rifle, a missile is *not* projected. It travels under its own power by means of a rocket motor. Some missiles are ballistic. They are powered by rocket for the initial stage of their flight and during this time are pointed towards their target. For the remainder of their flight they follow an unpowered, ballistic trajectory.

Guided missiles, on the other hand, are powered and guided all the way to their target. This can be

INERTIAL GUIDANCE

achieved by correction signals generated from equipment within the weapon as well as from messages transmitted from its parent aircraft or ship or ground-based controller.

The warhead

All missiles have a payload. This consists of some form of warhead which, in the case of an Intercontinental Ballistic Missile (ICBM), is a nuclear weapon. In most other instances it is a small explosive charge. The size of the charge will vary depending upon the task of the missile. If a missile is designed to explode in the vicinity of its target, rather than exactly on target, then the warhead it carries must be large enough to destroy it from a distance.

Some missiles — the British Aerospace Rapier Surface to Air

RADAR HOMING

Missile (SAM) for instance — are what is popularly called 'hittiles'. In other words they are designed to actually collide with their target every time. The warhead need not be very big — nearly 43 kg of missile hitting an aircraft at Mach 2 (twice the speed of sound) is enough to destroy an aircraft without the aid of an explosive charge.

An ICBM is in fact a small Space rocket but instead of being designed to place a small payload in orbit, it carries it on a trajectory that departs from the atmosphere only briefly, so that the payload will re-enter close to the target area.

MIRVs

The latest ICBMs have multiple independently-targetable re-entry vehicles, or MIRVs, which are designed to scatter up to ten separate

Gamma/Frank Spooner Pictures



warheads on the same number of targets. These MIRVs have a very accurate inertial guidance system which can be further refined to take a 'starshot' of the heavens to update their position. This is called stellar inertial guidance.

Given such accuracy and the ability to make powerful adjustments to the ballistic flightpath, targets can be reached with great precision over thousands of kilometres. There are also much shorter range, surface-to-surface, ballistic missiles such as the US Pershing II and the Russian SS-11 and SS-19

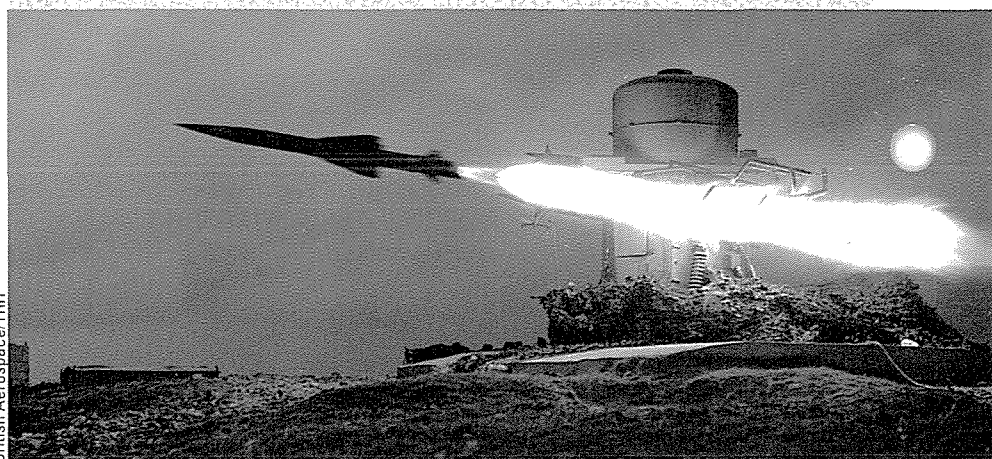


Cruise missile

In contrast with a ballistic missile, which uses all its energy in its boost phase to set it on the right course and trajectory, a cruise missile flies through the atmosphere using wings for lift and under continuous power, drawing oxygen from the air to mix with its own fuel. In essence it is an unmanned aircraft with a computer for a pilot.

Cruise missiles are relatively

THE RAPIER – SURFACE TO AIR MISSILE



British Aerospace/TRH

The British Aerospace Rapier SAM is in service with the armed forces of 14 countries. The Rapier's body is divided into four sections: warhead, guidance system, propulsion unit and control section. The nose is made of collapsible plastic, moulded to the best aerodynamic shape. When fired, the missile flies

towards the target at Mach 2 (twice the speed of sound). As long as the operator keeps the cross-hairs of his sights on the target it will score a direct hit. In this sense Rapier is termed a 'hittile'. When it hits its target, the direct action fuze explodes the warhead inside the target with catastrophic results.

Cruise missiles are computer controlled aircraft. Tomahawk, here flying over Mt Katahdin in Maine, USA, has a range of 3,600 km.

guided and the radar guided. An IR missile is fitted with a heat sensor and homes onto the heat emissions from the engine exhaust of another aircraft. By far the best known of IR AAMs is the US manufactured AIM-9 Sidewinder. The then USSR made a direct copy and mass produced it as the K-13.



All-aspect weapons

The original Sidewinders were designed only to home onto the hot exhausts of opponents' jetpipes from the rear quarter. Technological advances have given the current models such sensitivity that, when launched head-on, they will seek the aerodynamically generated warmth above a target's wings. Known as an

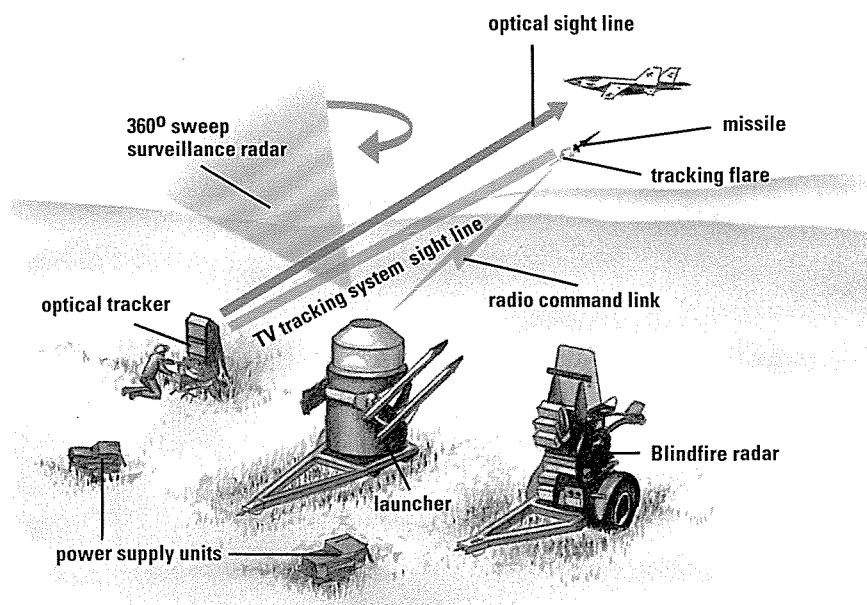
Scoring a hit with Rapier – once the target is sighted – is assured by the TV tracking system or, in fog or at night, by the Blindfire radar.

US Navy/DOD

small, cheap and flexible. In their launch tubes they can be fired from a wide range of launch platforms. In the Ground Launched Cruise Missile (GLCM) – The Tomahawk, for example – the missile rests in an aluminium canister with its wings, control fins and engine air inlet folded. On firing, a solid-propellant rocket booster punches the missile out. Its fins deploy, the wings fold out and the engine inlet pops down. The turbofan engine then starts up and after 13 seconds the booster motor burns out and is jettisoned.

The USA is now working on a new generation of cruise missiles that will fly supersonically, employ new forms of guidance technique and have radar baffling 'stealth' technology engineered into them. Cruise missiles can also be launched from ships, submarines and aircraft.

There are two main types of air-to-air missile (AAM), the Infra-Red (IR)



Matthew White



A Gazelle helicopter launches a French/German HOT anti-tank missile. All the operator has to do is keep the target in his sights and the computerized, optical tracking system guides the missile to it.

Douglas F-15 Eagle, which climbs to the edge of space to release the missile.

Air-to-surface missiles can be anti-ship, anti-tank or anti-radar. Some have a range of a few kilometres, others fly for over a hundred.

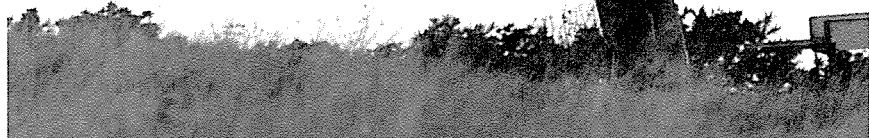
Most basic are the anti-tank missiles usually carried by helicopters and often no more than a slightly modified version of a weapon carried by soldiers or fitted to a jeep. Examples of this type are the US Hughes BGM-71 TOW anti-tank missile and the Euromissile HOT. When extra range is needed, the traditional missile solid propellant

Euromissile/TRH 'all-aspect' weapon, because the pilot has few concerns as to the relative position of his opponent, the AIM-9L can even be equipped with filters so that it is not easily decoyed by flares released by its intended victim.

For targets at longer ranges, when interception is less of a dog-fight and more of a cold-blooded affair, a medium-range missile is fired. The US AIM-7 Sparrow, the French Matra Super 530 and the British Skyflash are typical of such weapons. They all have Semi-Active Radar Homing (SARH) which means that they home on to the waves of their parent aircraft's radar, reflected from the target at ranges – in the case of the Sparrow – of up to 100 km.

The Americans have even developed an anti-satellite missile, the LTV ASAT, launched by a McDonnell

Surface-to-air missiles (SAMs), such as Javelin, have proved so successful in air defence that every fighting aircraft is equipped with warning systems.



Shorts/TRH

A Lockheed Trident II (D5), Intercontinental Ballistic Missile, being test launched from Cape Canaveral, Florida, USA. Closely allied to all such major weapons are the airborne early warning systems – AWACS – (inset) that keep a close watch on all aerial movement in US airspace.

motor is augmented by a miniature turbojet. The American AGM-84 Harpoon and the British Aerospace Sea Eagle are thus projected to a range of 100 kilometres or so.

Anti-ship systems

Both these missiles are 'fire and target' anti-ship missiles equipped with an inertial navigation system and active radar. After launch they fly to the given target location – which will have been supplied by friendly reconnaissance sources – then they engage their radar for terminal guidance.

Other anti-ship systems employ SARH like air-to-air missiles. Television and imaging IR systems employ an alternative guidance method in which a crew member in the launch aircraft controls the missile by radio using pictures transmitted by a camera in the missile's nose.

Anti-radar missiles are programmed to home on to enemy radar transmitters – presenting their operators with the option of switching off or being blown up!

Surface-to-surface missiles can vary from battlefield nuclear-capable missiles such as Lance with a range of 250 kilometres to hand-held anti-tank missiles with a range

US Navy/DOD



British Army



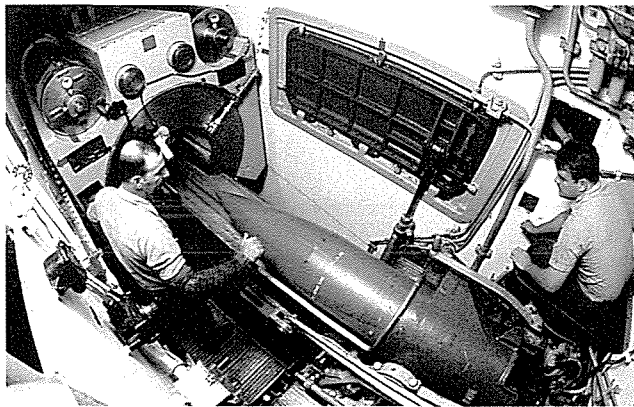
TRAGIC ERROR

On 3 July 1988 the *USS Vincennes*, was engaged in a surface battle against thirteen Iranian gunboats that were attacking merchant ships in the western approaches to the Straits of Hormuz in the Persian Gulf. During the engagement it fired an AEGIS missile at a plane that it had identified as hostile.

The aircraft, which was heading straight for the *Vincennes*, had been warned over the radio. Only weeks before, another ship, the *USS Stark*, had been hit by an Iranian missile with great loss of life. The aircraft had taken off from a military airfield and the *Vincennes* was in the midst of a battle. The Captain took a decision to safeguard his ship, but on this occasion he took the wrong decision – the plane was, in fact, Iran Air Flight 655 flying from a military airfield in Iran at Bandar Abbas to Dubai and all 290 people aboard – passengers and crew – tragically lost their lives.

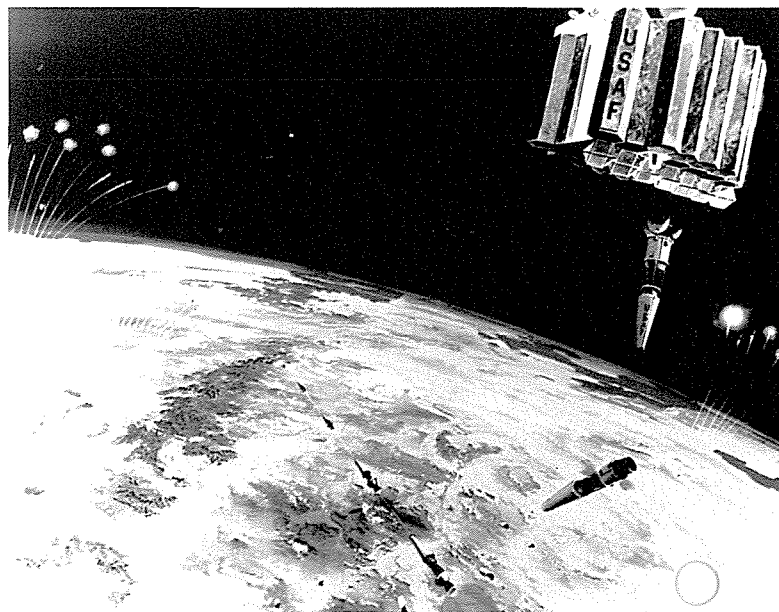
of only 3,000 metres. Surface-to-surface missiles are also fired from ships against other ships. The Exocet is perhaps the best known of these because of the devastating effect it had on Royal Navy ships during the Falklands War in 1982.

In the ship-launched version of this missile the target may be acquired in a number of ways, by mast mounted radar, for example, or fed in over the horizon by air reconnaissance.



Rex Features

Star wars has several guises. In this one an intelligent, rocket-powered missile is launched from a storage spacecraft (top right) towards enemy targets.

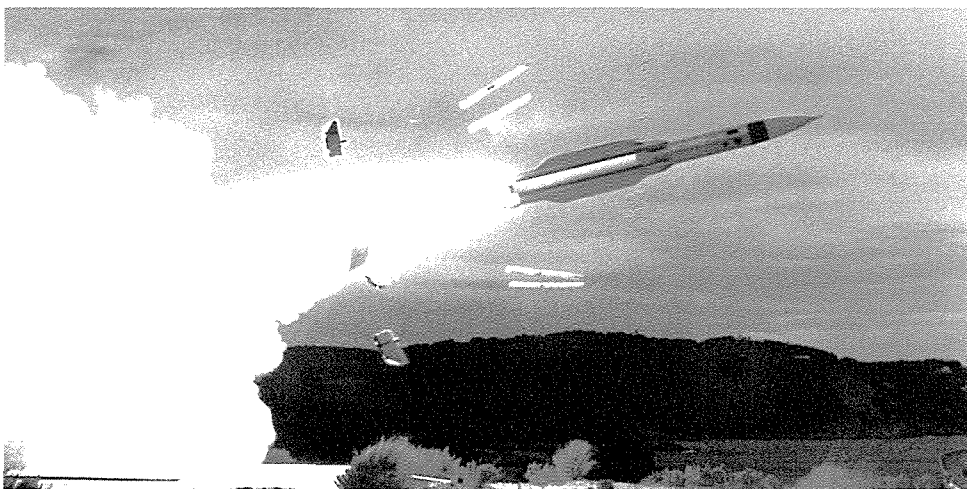


The M88 is a 'fire and forget', sea-skimming anti-ship missile. Launched from a ship or aircraft, it flies at over twice the speed of sound and can penetrate all defence systems.

speed is just short of Mach 4 and the missile can outmanoeuvre any aerial target.

'Hand-held' SAMs like the Russian SA-7 or the US Stinger home on to the heat emitted by an aircraft's engines, though the British Blowpipe and Javelin missiles are command guided – that is, the operator steers them on to the target.

USAF/DOD



Aerospatiale/TRH

After launch, the missile flies towards the designated point, descending in mid-flight to a few metres above the waves where it is hidden from the target's defensive radar system. In the last stage of flight the missile's active homing head switches on, flying the missile towards the centre of the ship.

Aircraft destroyers

Surface-to-air missiles (SAMs) are usually mounted on tracks but can be trailer mounted or, in some circumstances, fired from a fixed site. They are also fired from ships

at attacking aircraft.

The biggest SAMs, like the 140 km range US Nike-Hercules or the 250 km range Russian SA-5 Gammon, have nuclear warheads and were designed to blast formations of attacking aircraft out of the sky. But most are designed to take out single aircraft. The medium range US Patriot SAM system, which replaces its predecessors' multiple radar systems with one single-phased array system. This provides target early warning, lock-on, missile-tracking, command guidance and semi-active radar homing illumination. Flight



Paul Raymond



PORTABLE CDS

PERSONAL VIDEOS

MINIATURE TVS

Redferns



Future micro technology will enable you to watch a video image of a pop group, such as Big Fun (inset), as you walk down the street listening to their latest hit.

Michel Tcherevkoff/Image Bank

IN THE INCREDIBLE shrinking world of micro-electronics, computers, televisions, video players and digital stereos are fast approaching the point where the machines are smaller than the batteries that power them.

Gaillard/Jerrican

Among the first electronic devices to be made small enough to

clip on to the belt of a jogger or commuter were cassette-tape players. The latest compact disc (CD) technology is now also available in 'Walkman' form.

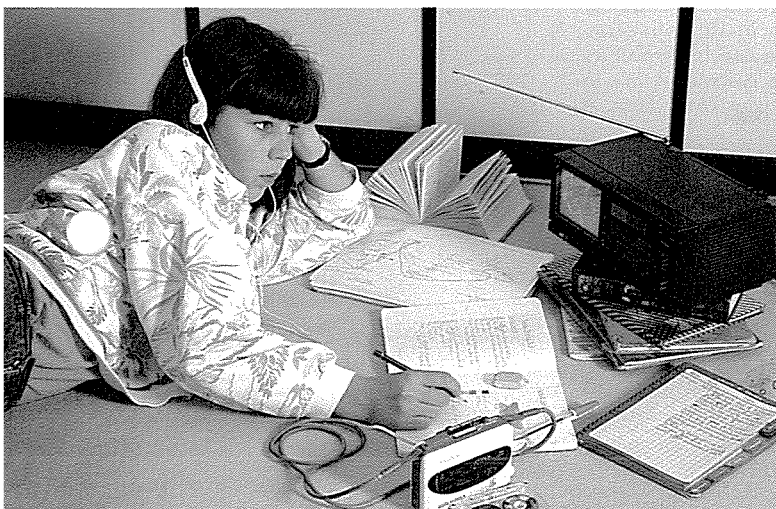
CD players, which work by scanning microscopic pits and blanks on a compact disc's mirror-like surface with a light beam, have fairly small moving parts to begin with. In

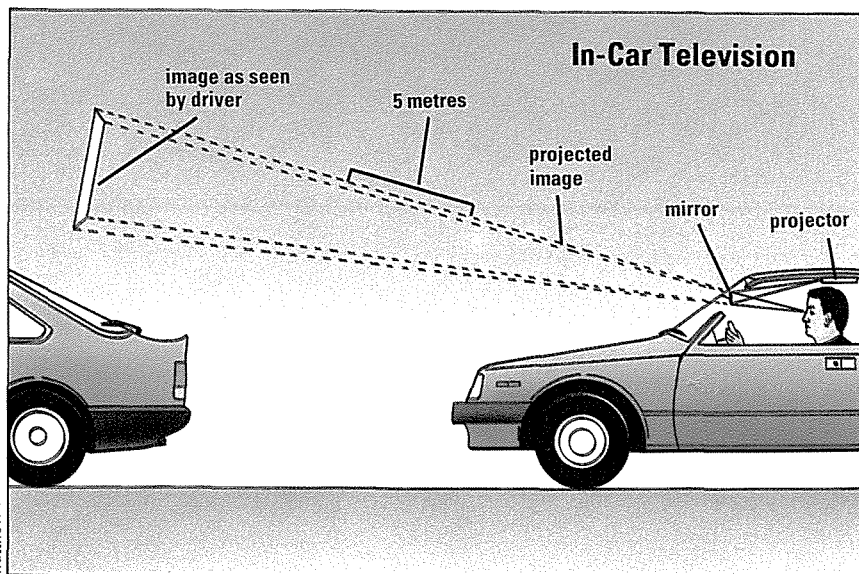
addition, there is no need for contact between the pick-up device and the sound surface, as, for instance, there is in the case of a record player. Thus CDs can be moved about without harming the sound or the machine.

Pocket televisions

Miniaturising television sets is more difficult. The problem is how to produce clear, moving pictures on a very small screen. Most ordinary TVs use cathode-ray tubes (CRTs), in which electric and magnetic fields control a beam of electrons fired at a luminescent screen. Pocket televisions, however, are now available that use an advanced kind of LCD (liquid crystal display). In contrast to CRTs, LCD screens run off only about 10 volts instead of 10,000 volts, and around one watt of power instead of tens of watts. Above all, they are extremely compact.

The personal cassette player is one of the great manufacturing success stories of the 20th century. Its inventor, Sony, sells over 10 million Walkmans worldwide every year, with rival companies making over 25 million imitations.





Autovision is a television viewing system for cars, which gives the driver the illusion that the image is in his or her normal field of vision.

Liquid crystal display

An LCD consists of a layer, about 10 micrometres thick, of liquid crystal. This is a substance in which the molecules can be made to line up in different ways by an electric field. The liquid crystal is sandwiched between two small glass plates. On to the inner surface of these plates, transparent electrodes are arranged in a grill pattern. These electrodes control how the molecules of liquid crystal are lined up.

Natural light falling on to the back of the LCD sandwich first passes through a polarizer, which makes the light vibrate in just one direction. The amount of polarized light reaching the front of the screen is then determined by the orientation of the liquid crystal molecules at

The Sony Video Walkman is a portable colour television and video recorder (using 8 mm film) with a tuner/timer.

each point.

One drawback of simple LCDs is that they cannot keep up with the rate at which a television picture changes. For this reason, manufacturers are now also placing small transistors at each grid point on the screen. The transistors act as fast, sensitive switches to control each element of what is called an active matrix display. Tiny red, green and blue filters can be fabricated at each grid location on the upper glass

THE LAST FRONTIER

Portable electronic equipment is just about as small as it can possibly be. The designers of portable video cameras and recorders, personal computers and pocket telephones all face the same problem. If the equipment is made too tiny it becomes impractical for humans to operate.

Another limiting factor is the size and weight of the batteries needed to power pocket-sized devices. Developments in miniaturisation of electronic circuits have far outstripped progress in battery technology. As an example, the smallest portable telephone available has a body, including keypad, display panel and aerial, that weighs less than 200 grams. The rechargeable battery used to power this device weighs at least half as much again.

plate to give a colour picture.

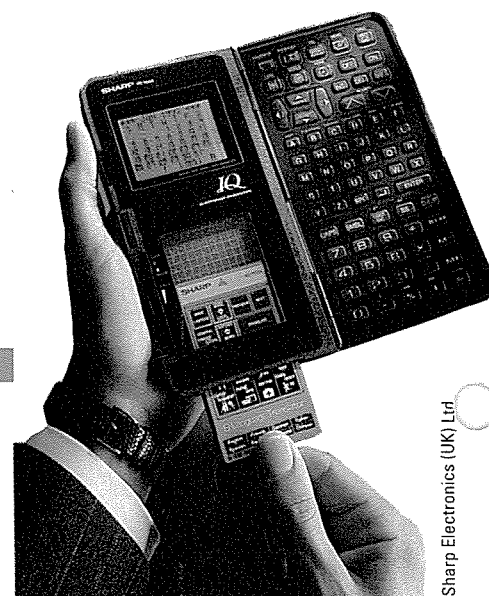
The portable TV is, however, facing a further revolution in its miniaturization. Imagine a device as small as a packet of chewing gum that fits in front of one eye and produces a full-size video image. Private Eye, developed by an American company, does just that. The device weighs just 60 grams and measures about 8 x 3 cm, with a viewing window 2.5 cm across. A user who holds the window up to one eye sees an image equivalent to a 30 cm TV screen half a metre away. This is superimposed on whatever the other eye happens to be looking at

and can be seen through if the user focuses on a point beyond the 'screen'.

Under wraps

The technology behind Private Eye is still secret, but there are two ways such a device could work. First, a small vibrating mirror might be used to direct a narrow beam of light on to a screen. If this is done fast enough, a complete picture on the screen would seem to appear instantaneously. Alternatively, a personal video could be built around an LCD display with a system of lenses to focus the image.

In future, devices such as Private Eye may be linked with pocket computers, video games and high-performance audio devices to provide the ultimate in multi-media entertainment.



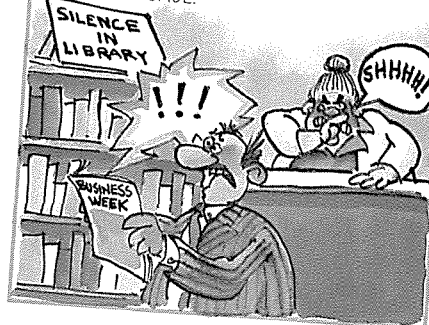
Sharp Electronics (UK) Ltd

Sharp IQ electronic organizer functions as a diary, address book and database as well as a calculator.

Just amazing!

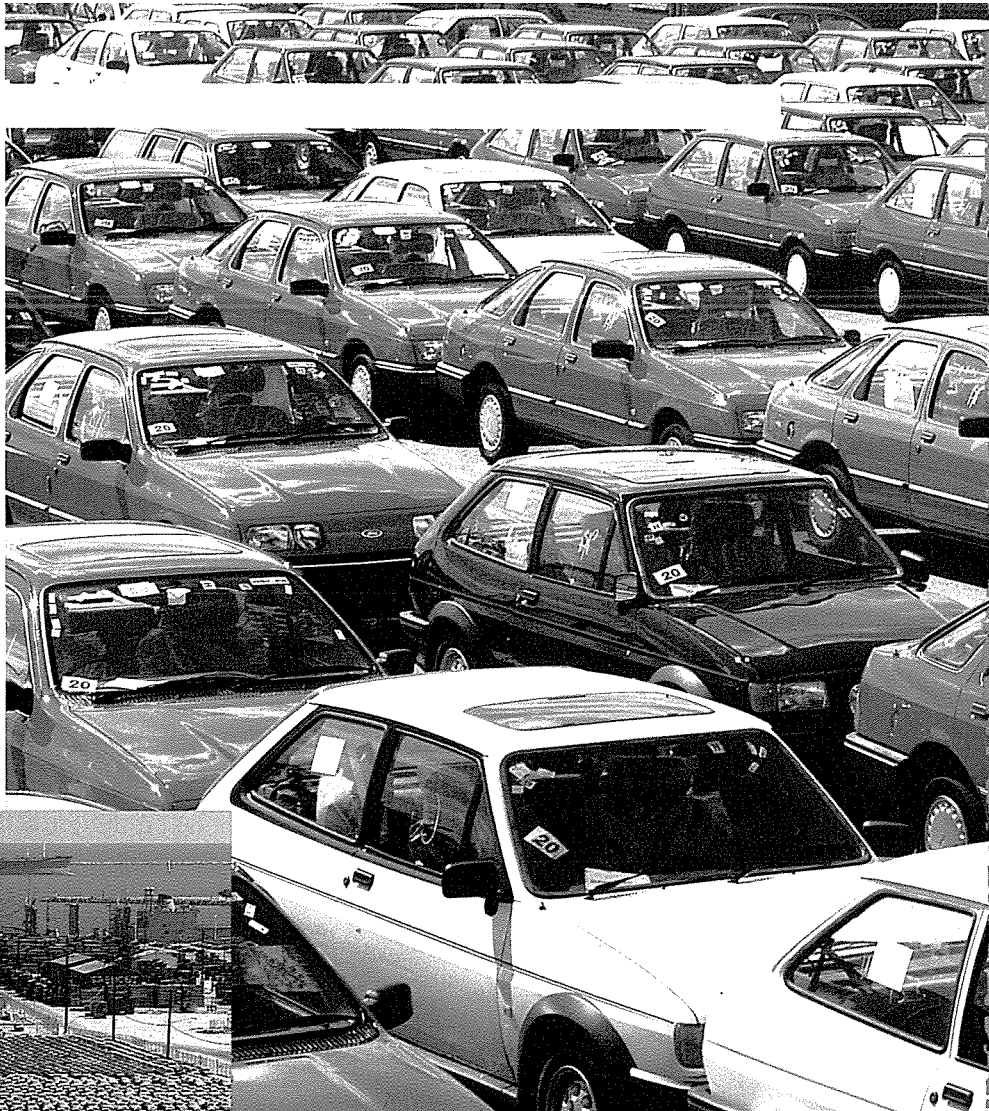
HARD SELL

THE WORLD'S FIRST TALKING ADVERTISEMENT FEATURED IN THE OCTOBER 20TH 1989 SPECIAL EDITION OF BUSINESS WEEK. EVERY TIME IT WAS OPENED, A MICROCHIP UTTERED ITS 42 WORD MESSAGE.



Paul Raymond

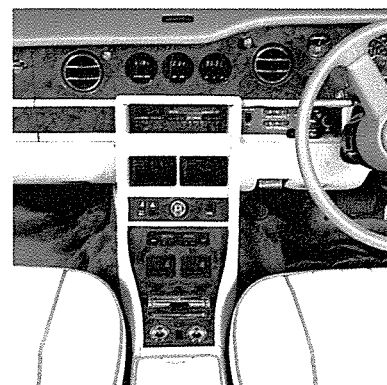
MASS MADE TO ORDER



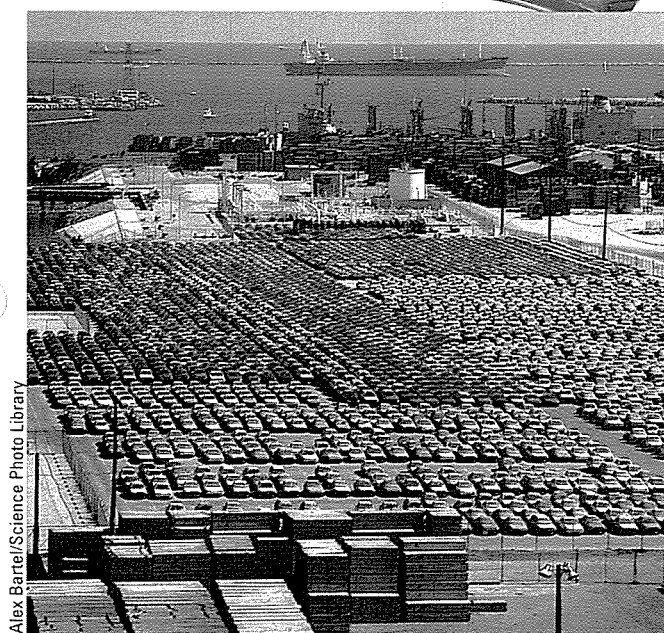
Tony Stone Photo Library, London

CRAFTSMANSHIP

Mass-produced – but with many options for the individual customer, hundreds of different imported models wait at the docks in Long Beach, California, USA (left).



Rolls-Royce Motor Cars Ltd



Alex Bartel/Science Photo Library

THE NEXT INDUSTRIAL revolution will be customized manufacturing. Having had his or her fill of the fruits of mass-production, the customer of the future will expect mass-produced goods to be made-to-measure – in batches of one.

Today, manufacturers of mass-produced goods are facing their toughest test since the introduction of the assembly line, first fully exploited by car-maker Henry Ford early in the 20th century. To meet the challenge, they must rethink how they produce goods and embrace the potential of automatic technology.

Conventional wisdom says that the more you produce, the cheaper each item will cost to make. But this does not naturally lead to flexibility; it is often difficult to modify an item to suit the changing demands.

Traditionally, for example, the 800-tonne presses used to stamp out car bodies in most Western car plants take about 4–6 hours to set up. This means that a minimum number of about 10,000 identical panels (about two week's supply) must be made before it is worthwhile changing the dies in the presses.



Smaller batches

In Toyota's Japanese car plant, however, the dies are fitted with quick-release fasteners instead of nuts and bolts and can be slid in and out of the presses in minutes. This means that much smaller batches can be made. Making things in smaller batches means that manufacturers can respond much quicker to changing tastes. In addition, individual production lines can make a greater variety of goods.

There is no such thing as a mass-produced Rolls Royce. Every vehicle is hand-made by teams of craftsmen, each working on just one facet. The veneers for the dashboard are cut from American burr-walnut. After passing quality checks, the veneer sheets are soaked in water and flattened in a press before being left to dry for four days. Only then can the craftsmen select the eight pieces of matched wood to make up the apparently one-piece fascia. A primer and three coats of polyester resin lacquer are applied to the finished dash, which is then sanded and polished to produce a glass-like finish.

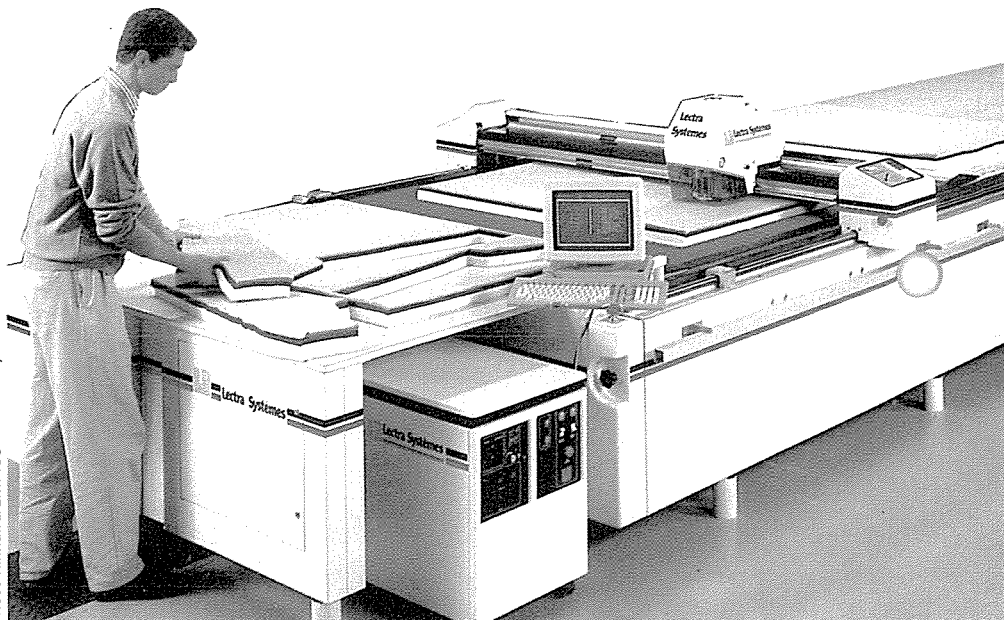


A similar revolution is taking place in the clothing industry. Already in use are automatic tailoring systems that can make patterns, mark and cut fabric and finish a suit — all from data fed in from a computer terminal in the shop.

The perfect fit

Researchers based at Loughborough University, Great Britain, have developed a scanner that even does away with the tape measure. Using banks of high resolution video cameras, the system takes three

Ross Kinnaird/EMPICS Lectra Systems Ltd



Automatic measuring systems combined with computerized cutting benches (above), can produce a made-to-measure suit in one hour.

minutes to measure up to 60,000 data points on a customer's body. This is used to create a 3-D image that records every curve and bulge.

At the same time, engineers at Belfast University, Northern Ireland, are able to combine the 3-D images with clothes designs to automatically create dress-making patterns. And a team at Hull University, Great Britain, has developed programs that instruct industrial robots to convert fabric into completed garments. Soon, high-street shops will be able to offer made-to-measure suits, at the push of a button, in one hour. And at a price to suit the average person's pocket.

Just amazing!

PAIR FOR THE COURSE

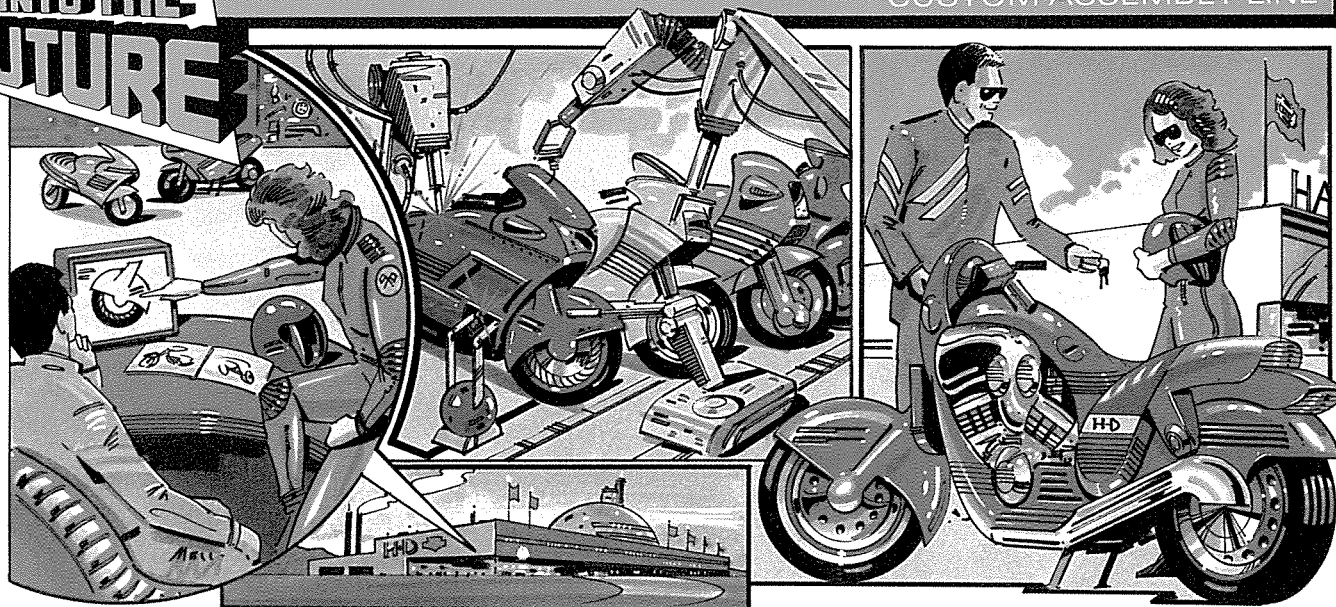
MINK-LINED GOLF SHOES WITH 18 CARAT GOLD TRIM AND RUBY-TIPPED SPIKES ARE THE MOST EXPENSIVE SHOES MADE. PRODUCED BY STYLO MATCHMAKERS INTERNATIONAL OF NORTHAMPTON, UK THEY SOLD FOR \$16,846 A PAIR IN THE USA.



Paul Raymond

INTO THE FUTURE

CUSTOM ASSEMBLY LINE



▲ In the motorcycle shop of the future, customers will be able to choose from a vast number of options, tailoring their machine to their own requirements.

▲ The order will be sent to the factory, where robots, instructed by the central computer, will assemble each motorcycle exactly to the customer's specification.

▲ Two weeks later the customer will take delivery of a unique motorcycle that has been built with standard parts and carries the manufacturer's warranty.

Joe Lawrence





STOLPORTS



MONORAILS



NOISE POLLUTION

AIRPORT 2000

CAUGHT BETWEEN THE NEED to handle greater numbers of air travellers and impose increasingly tough security, airports will need to undergo a revolution in the near future.

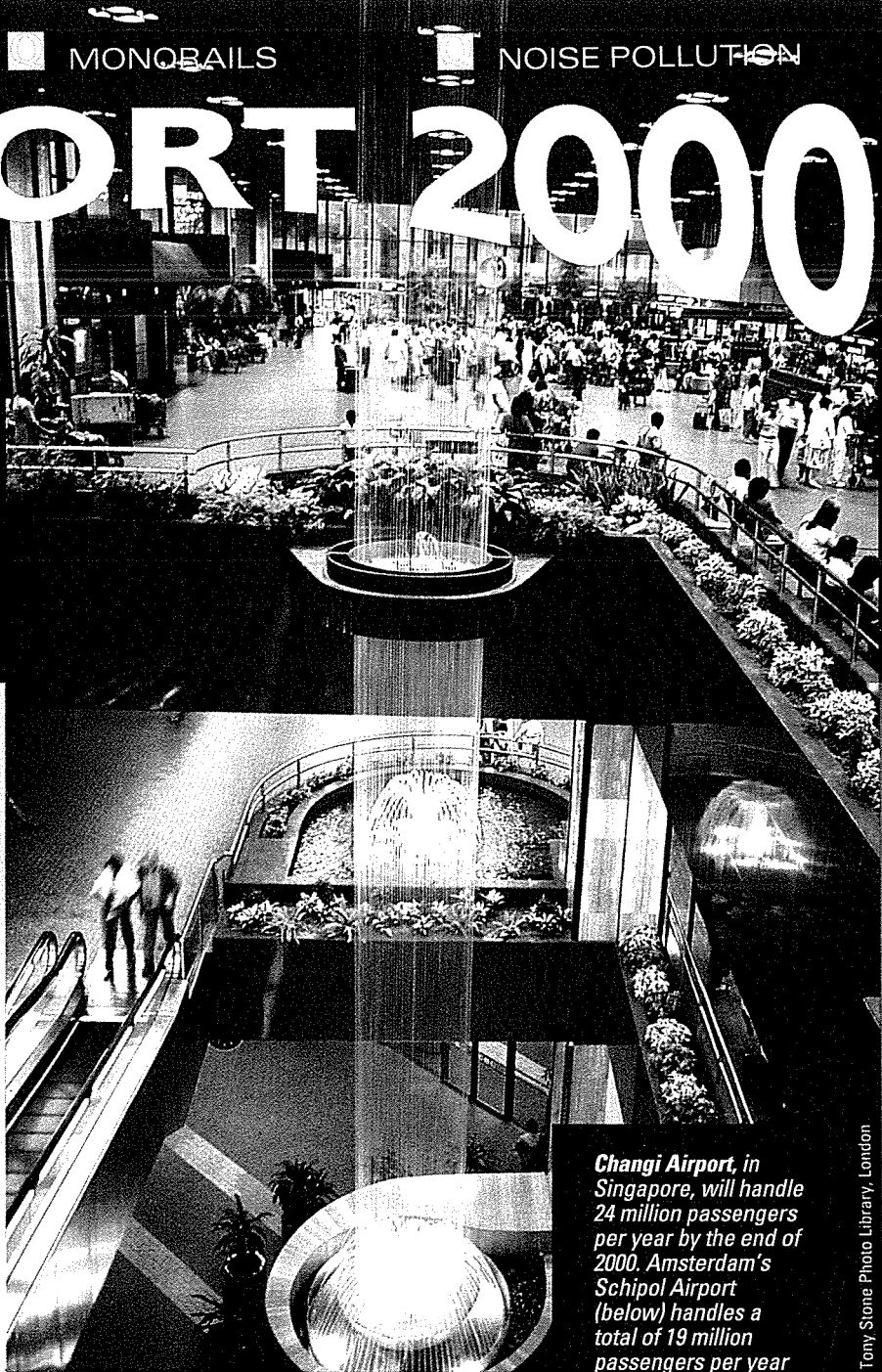
During peak hours at Chicago International Airport, for example, there is a take-off or landing every 39 seconds. Over 64 million people - more than the entire population of the United Kingdom - travel in or out of the airport each year.

One way to relieve the frustrating jam may be to build many small airports for handling short haul, Short Take off and Landing (STOL) planes. STOLports could be built in cities because their runways would take up relatively little space and STOL aircraft make far less noise during take off than conventional jets. Urban locations would reduce passengers' travel time.

Computerization

Much of the present congestion in airports might disappear if computers and robots took the place of human workers. Automatic ticket machines could take over from staff at the check-in desk; computers could be programmed to answer passengers' questions in different languages and robot baggage handlers could run security checks.

All this would mean that airports are equipped to cope with the growing number of passengers and the increasing security requirements of the future. But the airports



Changi Airport, in Singapore, will handle 24 million passengers per year by the end of 2000. Amsterdam's Schiphol Airport (below) handles a total of 19 million passengers per year with flights to and from 90 countries by over 80 airlines.

Tony Stone Photo Library, London



moved around using interlinking systems of automatic trains, escalators and moving walkways.



Security

At the same time, airports will have to continue to tighten up on security. Smuggled weapons, drugs, and other illegal items are just part of the problem. With increasing air traffic there is also the danger that diseases and insect pests may be transported from country to country.

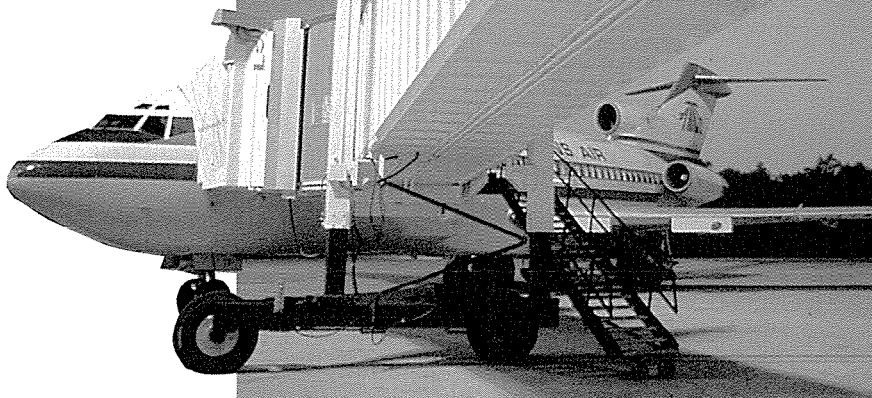
Tomorrow's passenger aircraft will bear little resemblance to those in service now. Some will be capable of climbing steeply to the edge of space and cruising at speeds of between 25,000 and 38,000 km/h. This would enable, say, a business executive to fly from London to Tokyo in the morning, attend a meeting there in the afternoon and return to London the same evening.

Less swift, but with greater capacity would be a large amphibious plane. Designed to alight or take-off from land or water it could use any small city-centre airport bordering on an ocean, lake or river.

TAKING ON FUEL

A jumbo jet uses as much as 8,000 litres of aviation fuel per hour when in flight. Its tanks may hold up to 100,000 litres of fuel weighing 50 tonnes – enough to keep a family car going for about 100 years. Between flights the aircraft is refuelled from tankers with a capacity of between 20,000 and 40,000 litres. High-speed pumps enable a Boeing 747 to have its tanks completely filled in about 20 minutes. The amount of fuel taken on board depends on the aircraft's load, the distance it has to travel and the forecast direction and speed of the winds.

Boarding bridges adjust to aircraft in any parking position to protect passengers from weather, aircraft engine blast and dust.



Jetway Systems

Powered by an atomic fusion engine, it would be able to transport 1,000 passengers and more than 135,000 kg of cargo at a cruising speed of 960 km/h.



Seadromes

Coastal airports, or seadromes, built on long platforms jutting out into the sea, could become increasingly popular. In remote areas they would have the advantage of having no surrounding hills or buildings to obstruct airliners landing and relatively few people would be affected by their noise. Fast, pollution-free ground transport, like electric monorails,

Automated baggage handling in airports is speeding up a previously lengthy process. The optical character recognition system (below) sorts luggage at the rate of 60 bags per minute.

Just amazing!

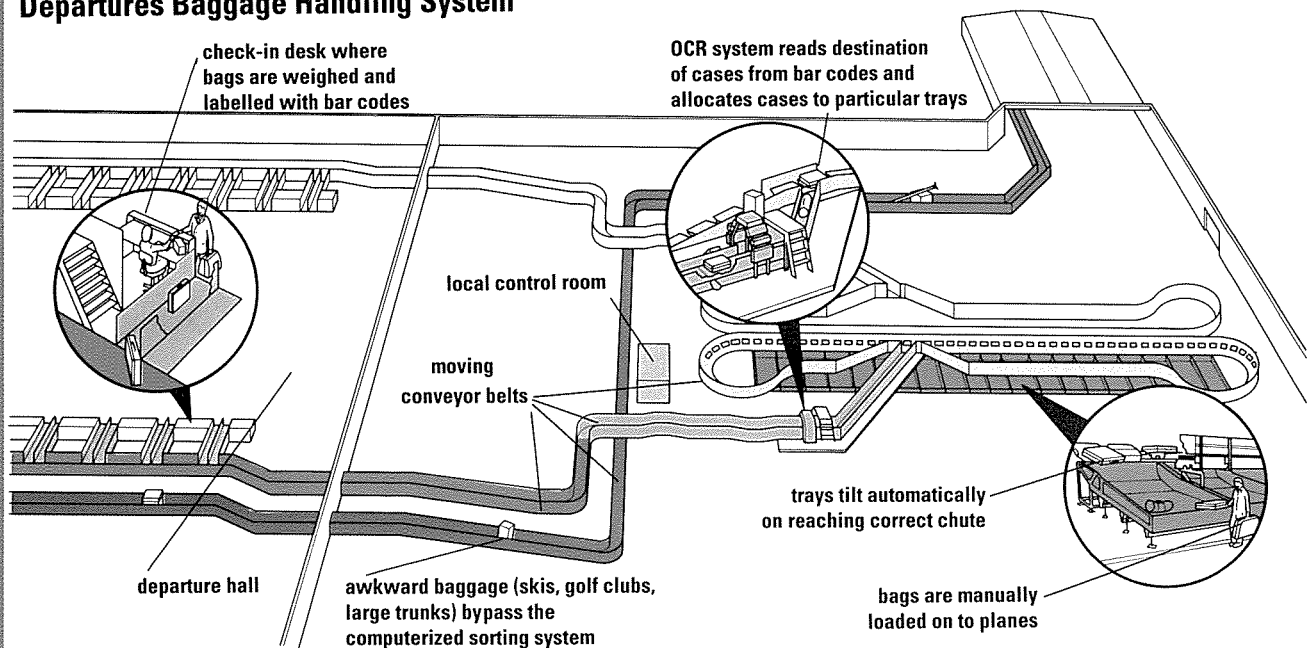
PLANE CRAZY

DALLAS FORT WORTH AIRPORT PLANS TO EXTEND TO HANDLE 150 MILLION PASSENGERS PER YEAR – ABOUT THE SAME AS THE POPULATION OF BRAZIL – FROM NINE RUNWAYS, 13 TERMINALS AND 260 GATES.



Paul Raymond

Departures Baggage Handling System





MELTING ICE-CAPS



FLOOD DAMAGE



SEA DEFENCES

RIISING SEAS

Stone Picture Library, London

Icebergs will disappear along with the north polar ice-cap if global temperatures rise by as little as 4°C.

Flooding is then likely to affect low-lying areas with some coastlines disappearing completely.



Gamma/Frank Spooner Pictures

densely populated and largely unprotected Nile Delta in Egypt and the Ganges Delta in Bangladesh.

A rise in sea-level of just 50 cm would swamp the hugely fertile Nile Delta, affecting nearly 16 per cent of Egypt's population. A 2-metre rise in the sea level would affect 21 per cent of that nation.

Climate also may change permanently, with tropical regions

THE GREENHOUSE EFFECT is causing the Earth to warm up and the polar ice-caps to melt. Already the sea-level has risen between 10 and 15 cm since 1900. By the year 2030, higher average temperatures and rising sea-levels may mean widespread flooding around the world.

As the global temperature rises, the Arctic icepack will melt. But this will not cause a significant rise in sea-level. The Arctic icepack floats so, like an ice cube in a cool drink, it displaces the same volume of water that it forms when it melts.

Glaciers melting will not affect sea-levels much either. The melting of the glaciers would probably be more than offset by the increased snowfall - one result of increased

evaporation that would follow from warmer seas.

However, there is some danger that part of the Antarctic ice sheet may break up if the warming continues beyond the 21st Century. This by itself could produce a rise in sea-level of up to six metres! The most direct consequences of rising seas will, naturally, be felt around coasts. Some three billion people live in vulnerable coastal areas.



River deltas

Other immediate effects are expected to be the loss of agricultural land by the flooding and erosion of river deltas. In addition, some rivers may silt up and more salt water in river estuaries will affect drinking water. The most acute effects are likely to be experienced around the

Just amazing!

TO CAP IT ALL

SOME SCIENTISTS BELIEVE THAT THE POLAR ICE CAPS ARE GETTING THICKER! ONE OF THE SOLUTIONS IS TO COVER THE ICE CAPS WITH BLACK PLASTIC SHEETS TO ABSORB HEAT FROM THE SUN AND MELT THE ICE.



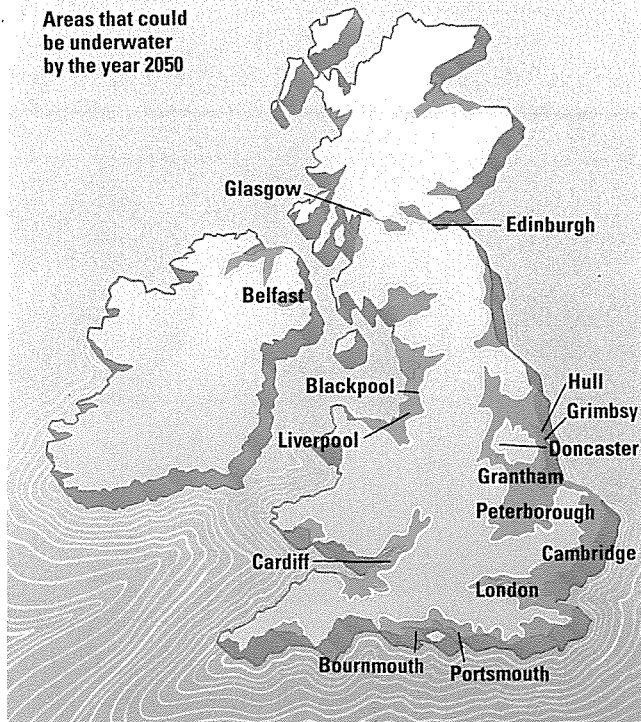
Paul Raymond



Key

Areas that could be underwater by the year 2050

UK Coastline - 2050



Joe Lawrence

spreading further north and south. This may be accompanied by the creation of new deserts in central Africa, northern Australia, South America, California and southern Europe.

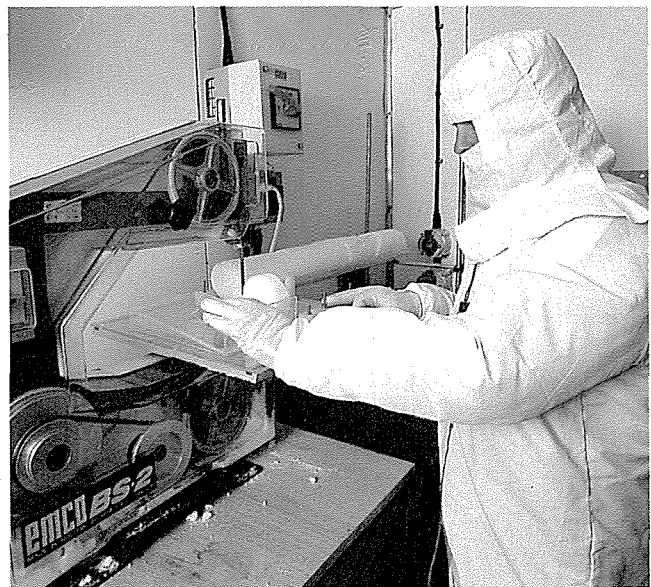
In Bangladesh, a 2-metre rise in sea-level would lead to a loss of up to 28 per cent of the land area. Storm

A glaciologist uses a saw to cut a section of an ice core from Antarctica. Analysis provides evidence of past changes in climate and of current trends in pollution.

Forecasts based on calculations by scientist, Dr Michael Tooley, of Durham University, UK, indicate that by 2050 global warming may result in the seas around the UK rising by up to 7.5 metres. This would swamp many parts of the UK, including London, Belfast and Glasgow.

STEAMING PLANET

Thousands of millions of years ago, Venus had a surface temperature similar to that of the Earth. But a series of volcanic eruptions threw vast quantities of carbon dioxide into the atmosphere. This formed an invisible blanket, just like the panes of a greenhouse, that let the Sun's rays in but stopped the heat from getting out. The temperature rose gradually until the seas began to boil. The vast clouds of steam this produced was trapped by the blanket of gas and 'pressure-cooked' the planet until its surface was about 400°C – four-and-a-half times that of boiling water.



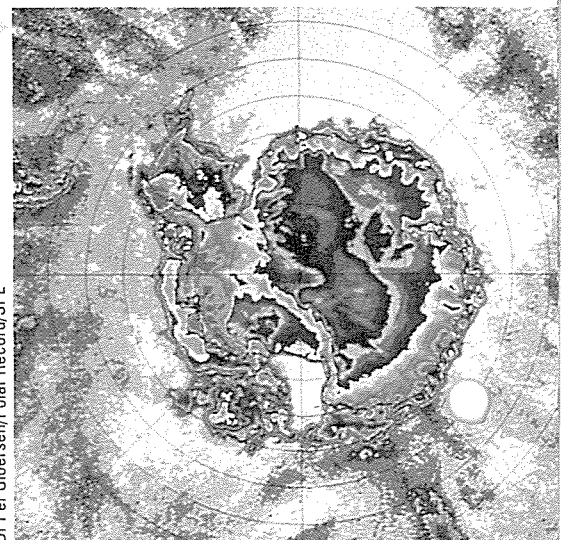
Simon Frith/Science Photo Library

The Thames Flood Barrier, with its 10 gates designed to swivel upright if London is threatened by high tides, could cope with a tidal rise of up to 4 metres.

southern England, which was also affected. But a 1-metre rise in sea-level would defeat these sea defences. Even London's Thames Barrier could be overwhelmed.

New York and Ocean City, USA, and Rio de Janeiro, Brazil, would all be affected by serious flooding if sea levels rose. Further inland, docks, ports and transportation systems around tidal rivers would all be vulnerable.

'Brightness temperature' maps of Antarctica, taken by satellite, are compared to discover trends in the extent of the polar ice sheet.



Dr Per Gloersen/Polar Record/SPL

surges which occur when storms coincide with high tides, could then penetrate further into the country. In 1988 floods inundated 62 per cent of Bangladesh.

A number of low-lying islands would also be vulnerable. The Maldives, for example, are a cluster of more than 1,200 coral islands southwest of the Indian subcontinent, which rise to a maximum of only 2 – 3 metres above sea-level. The growth of coral will offset the rise in sea level on some islands. However, the coral does not

grow so fast on islands that are heavily populated.

Flood warning

But it is not just the Third World that would be affected. Low-lying areas in other parts of the world have already been subjected to flooding by the sea. In 1953, a storm surge in the North Sea submerged part of Holland, drowning 1,835 people and covering 150,000 hectares of farm land with infertile silt and salt.

Since then, huge sea defences have been built in Holland and in

Ben Johnson/Science Photo Library



MICRO

ENGINEERING



The scanning probe microscope, billionths of a centimetre above a surface, reveals details smaller than an atom.

NANOTECHNOLOGY PROMISES a world of microscopic machines measured in nanometres – billionths of a metre. Built atom by atom, such devices could reproduce themselves to create a vast, unseen army of robot workers.

Ordinary microscopes cannot show detail that is smaller than the wavelength of light, or about one five-thousandth of a millimetre. But, by using a scanning probe microscope scientists can detect and record images of single atoms – opening up the possibility of nanotechnology.

All solids are covered with a fuzzy cloud of charged particles called electrons. In a scanning probe microscope, a tiny diamond needle is lowered to within a few billionths of a centimetre of the surface to be studied. This causes the electron

clouds of the surface and needle to overlap and electrons can jump back and forth between them. The result is a minute electric current. As the needle scans the surface, it is raised and lowered by incredibly small amounts to keep the current constant. A 3D image is formed from a record of these up and down movements. In this way, detail smaller than the width of an atom has been observed.

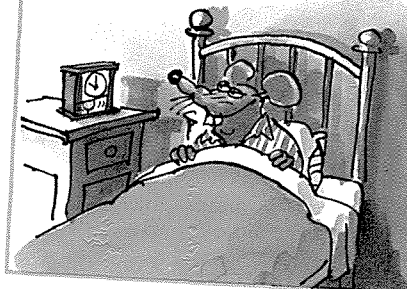
Electron beam drill

Some of the latest types of microscope can be used not just to see things in fine detail, but to read and write information on an amazingly small scale. A scanning electron microscope works by bouncing beams of electrons off objects and measuring the way the beams are affected by the surface layer of atoms. The scanning

Just amazing!

NO ROOM FOR THE CUCKOO

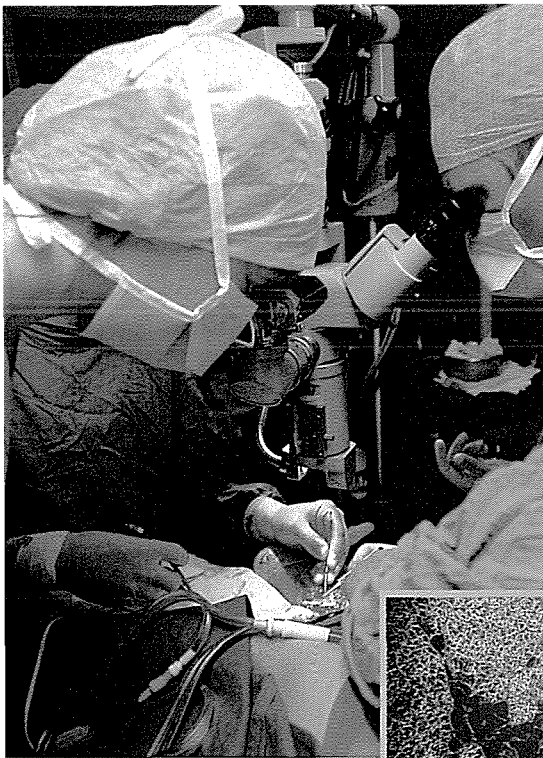
IN 1988 FREDDY SUESS, A SWISS WATCHMAKER, CLAIMED TO HAVE THE WORLD'S SMALLEST PENDULUM CLOCK. MEASURING JUST 1CM TALL IT WEIGHS 1.5 GM ITS PENDULUM SWINGS 3 TIMES A SECOND!



Paul Raymond

WA Technology Ltd

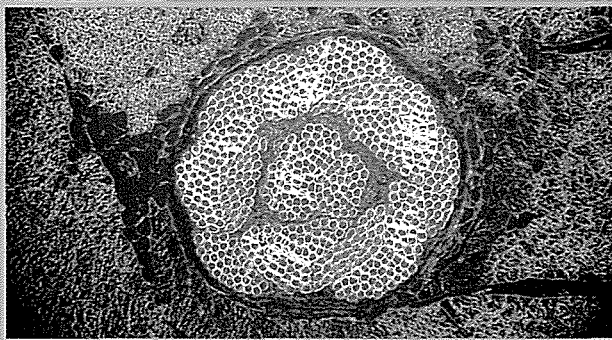




Jim Stevenson/Science Photo Library

Surgeons use an operating microscope to join two blood vessels. The thread itself (right) is just 0.005 mm across.

Cecil H Fox/SPL



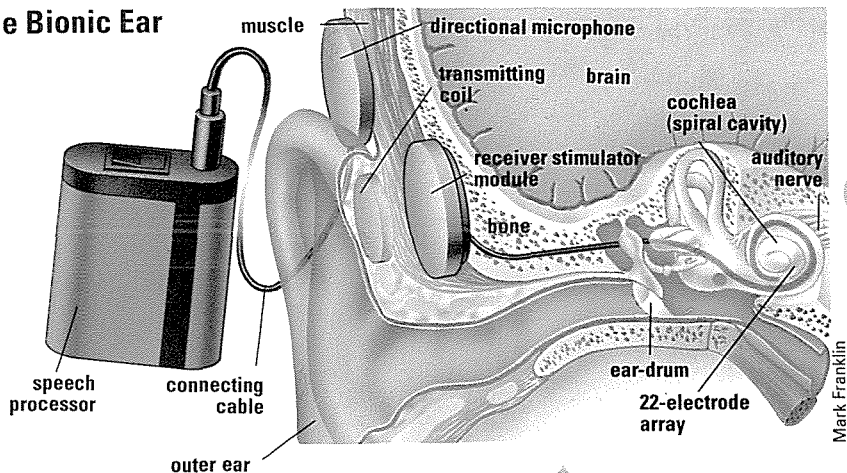
electron beam can also be used to drill miniscule holes as small as 4 nanometres – 4 billionths of a metre – in diameter.

In 1988, scientists at Cambridge University, UK, used this method to produce a copy of their group's Christmas card – a drawing of a robin. The result was easily the world's smallest ever greeting, only 5 square micrometres in area, or one

billionth the size of a conventional card.

The dream of nanotechnologists is to build machines out of atoms. Microscopic submarines could someday roam the human body, destroying unwanted organisms, such as cancers, and fatty deposits in the blood vessels. The tiny engines would be fuelled by glucose and oxygen, absorbed from the bloodstream.

The Bionic Ear



Mark Franklin

The bionic ear feeds sounds from a small microphone to an implanted receiver which then sends signals to 22 electrodes on the patient's inner ear.

If it bumped into the wall of a blood vessel or a red blood cell, for example, the sub would reverse its engines briefly, then continue on its way. If it bumped into a hostile bacterium or virus, however, it would open a pair of mechanical jaws and swallow it.

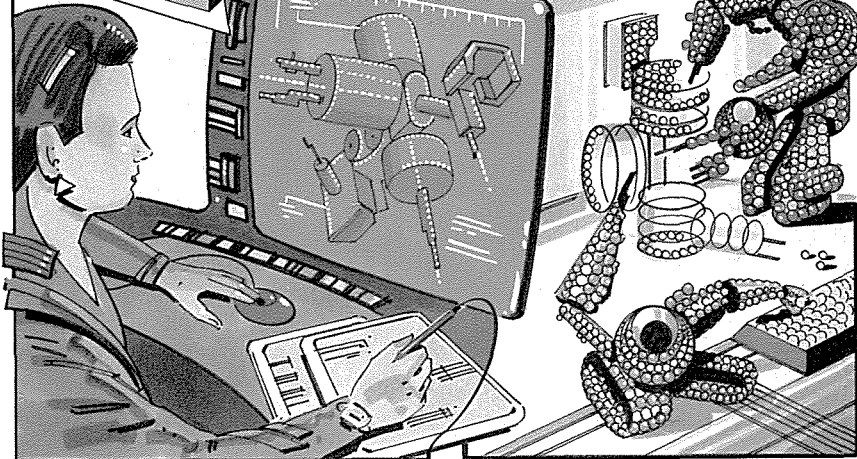


Sub-atomic supercraft

Ultimately, nanotechnologists foresee even smaller machines, with moving parts just a few atoms across. These 'supercraft' could roam the body, invading cancerous cells, for example, and rearranging their DNA to render them harmless.

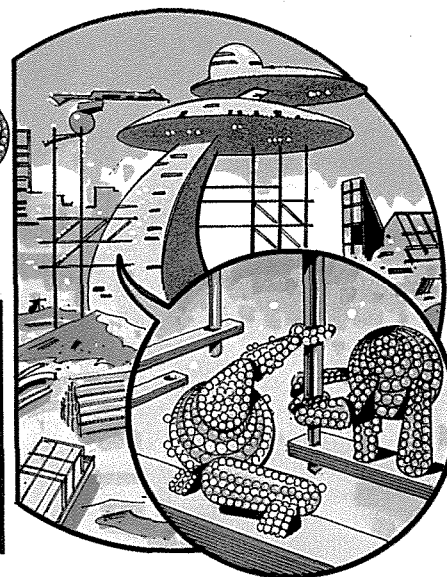
K. Eric Drexler, of Stanford University, USA, seen by many as the father of nanotechnology, has even devised a nanocomputer.

INTO THE FUTURE



▲ Future developments in micro-engineering may make it possible to design entire machines that are only a few nanometres in size.

▲ Such devices might be assembled molecule by molecule by pre-programmed factories, themselves no larger than a grain of sand.



▲ Miniature machines could be released on a construction site as a barely visible film and in a few weeks they could erect an entire building.

Joe Lawrence



SUPER CERAMICS

Q REFRACTORIES

Q TUNGSTEN CARBIDE

Q FUTURE ENGINES

Ceramic moulds are used to cast molten metal in furnaces at over 1000°C.

Tungsten carbide is a ceramic used to tip tools that machine metal.

CERAMIC MATERIALS ARE virtually indestructible. Unlike most other materials they are impervious to heat and do not corrode in air or water. Yet because of their brittleness, they used to have a limited range of uses. Now that scientists have developed ceramic materials that are not so brittle, potential uses are just beginning to be realized.

Ceramics are far from new. A ceramic material is simply a piece of clay that has been heated, or fired, to a high enough temperature to make it permanently hard. People have been making clay pots for over 10,000 years and today almost every house contains ceramic materials – in the form of bricks, tiles and china plates.

The most important property of a ceramic is its ability to withstand heat. Some ceramics do this better

than others. Those that can be heated to temperatures of over 1000°C without melting, fusing or decomposing are described as being refractory.

In the furnace

Refractory materials have a number of important industrial uses. For example, a blast furnace (used to extract metallic iron from iron ore) is lined with refractory bricks that prevent the steel shell of the furnace from melting. After a long period of continuous use, however, the bricks begin to disintegrate, at which point the furnace has to be shut down and relined with new refractory bricks.

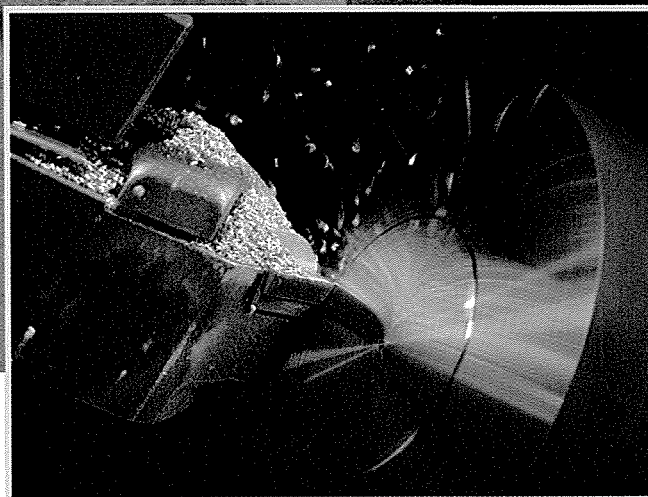
Refractory bricks are made from clays and sands that contain a high

proportion of silica (silicon dioxide). When this is fired at a temperature of 1400°C, its structure changes to one that is completely stable when heated.

Miracle Material

Another type of ceramic is made from the mineral dolomite, which contains magnesium and calcium carbonates. Fireclay is made from rock containing alumina (aluminium oxide). Alumina is used as the base material for printed circuits. Porcelain is made from the mineral kaolinite (a form of aluminium silicate) and is widely used to make such things as electrical insulators, as well as many household ornaments.

In recent years, a completely new



Paul Brerley

Ben Johnson/Science Photo Library



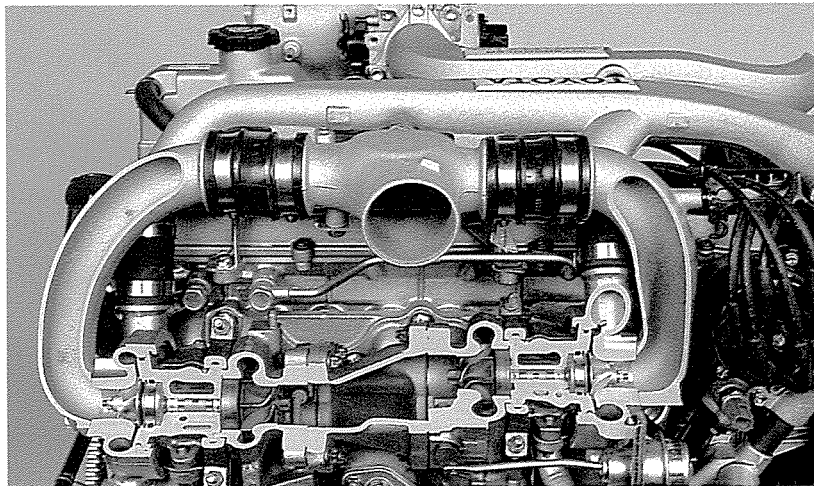
range of ceramics has been developed. These are harder, stronger, more heat resistant and better able to withstand sudden temperature changes than ordinary clays. Among the new materials are the aluminium oxide ceramics used to make the insulators of engine spark plugs and the heat shields of spacecraft, which can withstand temperatures of up to 2100°C. Zirconium oxide ceramics can withstand up to 3000°C and are used in the study of metals.

Other new ceramics include oxides of beryllium, thorium and

of NASA's space shuttle. Ball-bearings and the cases of some silicon chips are now made of ceramic, and a Japanese company has produced ceramic ball-point pens, scissors and knives. Some artificial human body parts are now available, such as elbow, hip

strong. They are used, together with the fabric Kevlar in the manufacture of bullet-proof vests. When actually mixed with fibres to make ceramic-fibre composites they make extremely tough, flexible materials that absorb energy. Ceramic-metal composites, known as cermets, are

THE CERAMIC ENGINE OF THE FUTURE



Toyota Motor Corporation

The dream of today's materials scientists and engineers is to build a ceramic car engine. It could run at a much higher temperature than existing metal engines so it would be less polluting and more fuel-efficient, and would not need a radiator for cooling.

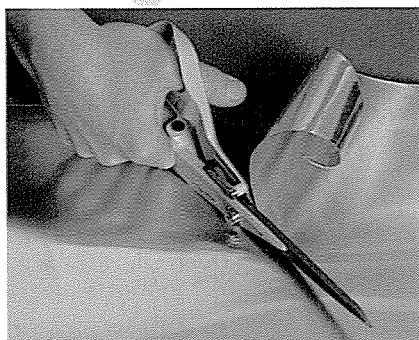
Engines that contain ceramic cylinder linings, pistons, valves and turbochargers have already been built. American engineers are designing a gas turbine (jet) engine for cars, the power turbine and the combustion

chamber of which are made of ceramics.

There are problems though. Ceramic car engines would need to operate at around 2,500°C, compared to the 800°C reached in the cylinders of ordinary metal engines, and the ceramics used today tend to fail above 2,200°C.

Also the materials and testing procedures involved are very expensive. So it could be some time before we see the first high-temperature, super-efficient, environmentally friendly ceramic car engine.

Scissor blades tipped with the ceramic compounds of zirconium are tough enough to cut sheet metal.

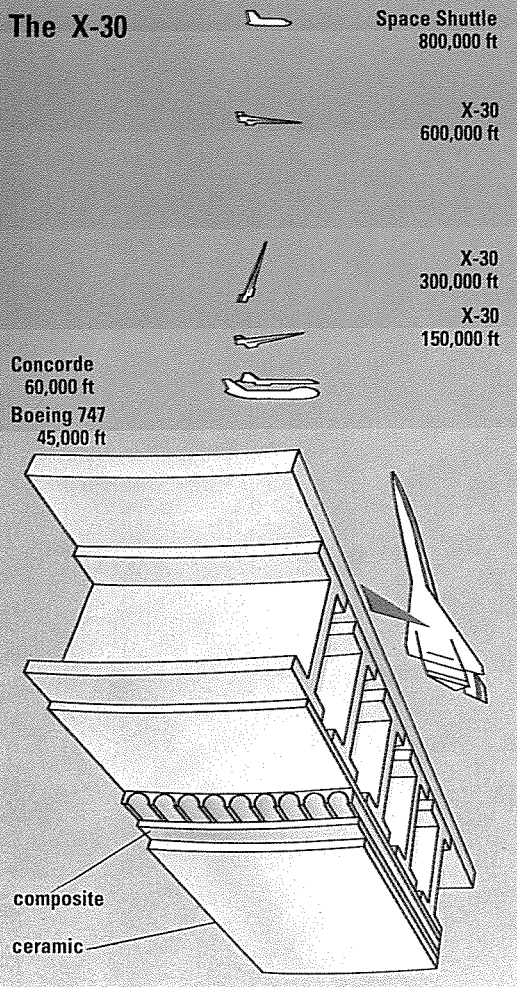


Ivaldi/Jerrican

also being investigated for making such things as the cylinder blocks of motor cars instead of using only metal.

Ceramic lining may also be used for the combustion chambers of future missile engines.

The X-30



Mark Franklin **The experimental X-30 hypersonic plane will need a ceramic skin to cope with heating at Mach 25.**

magnesium. Silicon and titanium nitrides have a wide range of uses. Carbon-containing compounds, known as carbides, are extremely hard. Tungsten carbide is used in machine tools, such as lathes and drills, and silicon carbide is used in the form of granules on grinding wheels.

New uses

The range of uses for ceramics is increasing rapidly. Ceramic cooker hobs are made of silica, as are the fibrous tiles that form the heatshield

and knee joints, contain ceramic materials.

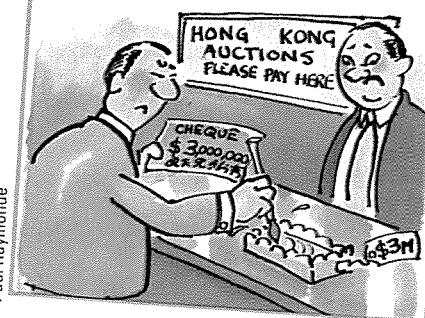
Ceramics are very porous and this property is exploited in the anti-pollution device known as a catalytic converter, used in some car exhaust systems to change harmful gases into harmless ones. The honeycomb material inside the catalytic converter is made of a ceramic coated with a mixture of platinum, palladium and rhodium.

Ceramics are brittle but very

Just amazing!

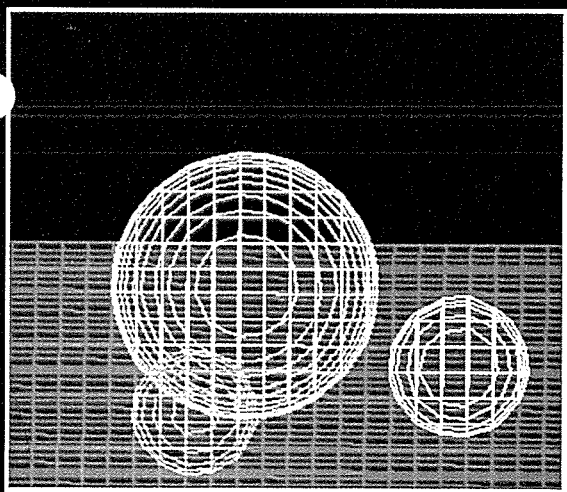
NOT CHEAP CHINA

AT AN AUCTION IN HONG KONG IN 1989, AN ANCIENT CHINESE PORCELAIN BRUSHWASHER WENT FOR THE HIGHEST PRICE EVER PAID FOR ANY CERAMIC ITEM - ALMOST \$3 MILLION.

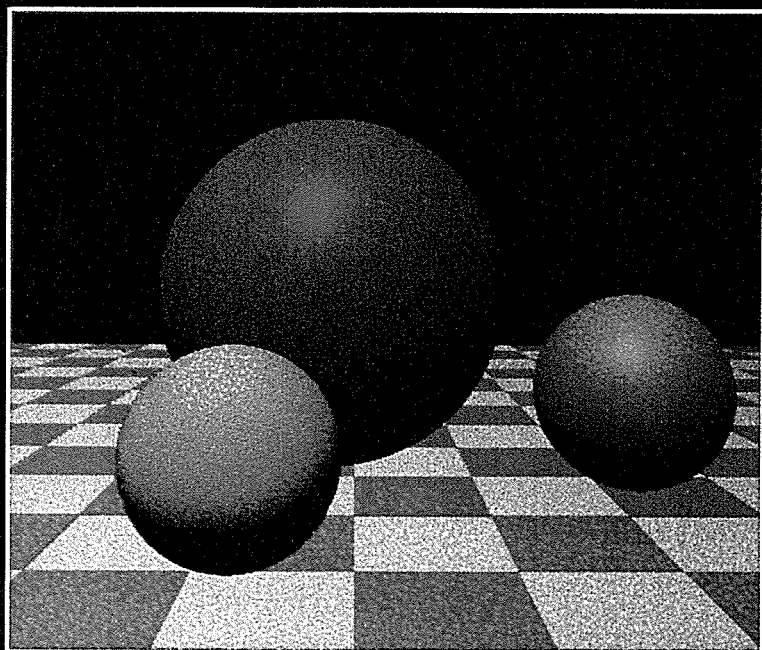


Paul Raymond





ELECTRONIC ART

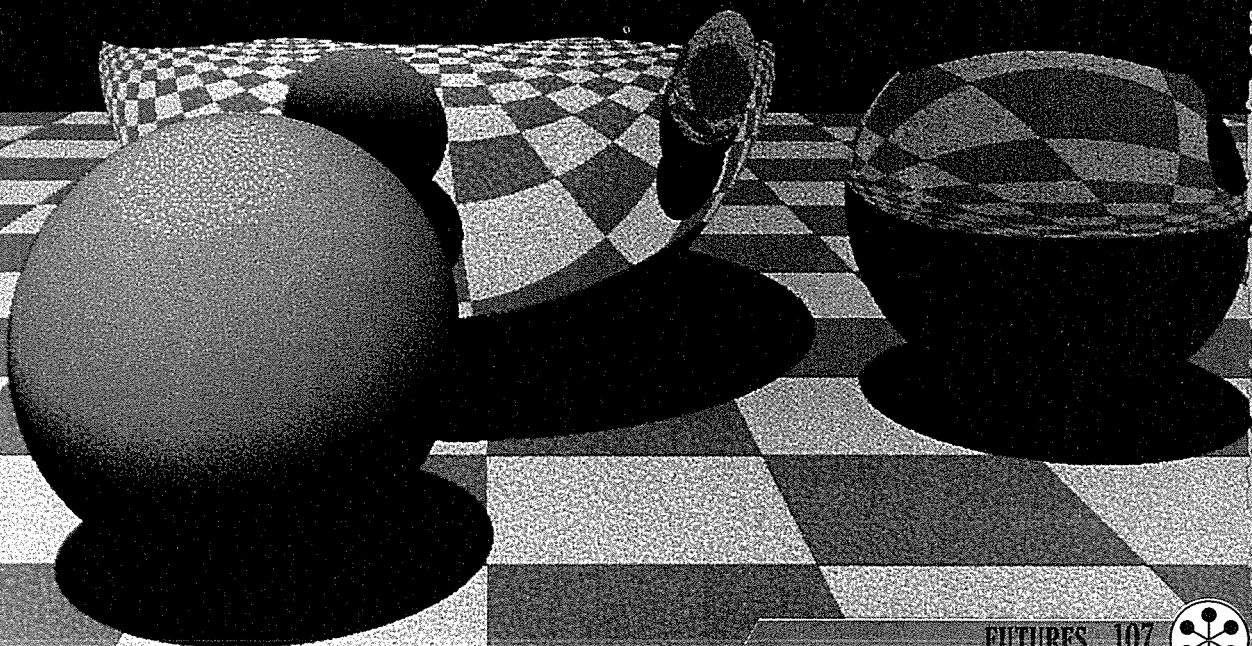


ON A COMPUTER SCREEN A form like something from a dream - or a nightmare - grows and develops. It branches, twists and transforms itself. Around its edges new forms sprout, duplicating parts already existing. It grows into a fantastic creation, partly resembling a bird, partly resembling a sea-creature.

This creation is called a 'sculpture' - but a sculpture that cannot be touched and has no existence outside the computer. It is a form obtained mathematically, by repeatedly applying a small number of rules to a basic pattern. The sculptures are made by the artist William Latham, who was invited by the giant computer company IBM to work with their hardware and

William Latham/IBM UK SC

Computer images can be given a wire-frame (top left) or solid appearance (left). Shadows and reflections can also be added to the images (below).



COMPUTER PAINTING

Creating and altering pictures becomes a matter of mathematics in the computer age. A computer stores a picture as a long string of numbers. Typically a picture on a personal computer screen may be made up of 400 rows, each with 640 dots of colour. These dots are called 'picture cells' or pixels.

In a black and white picture each pixel may have 16 levels of brightness, ranging from 0 (black) to 15 (white). To increase the contrast of the picture, for example, the darker levels (say from 1

Quantel



to 4) can be changed into the lighter ones (from 11 to 14).

In a colour picture each pixel may have any of perhaps 16 colours. Colours can be switched round – red going to orange, orange to yellow, yellow to green and so on – by altering the numbers according to a rule.

make the surface look glossy, rough or bumpy. To simulate a smooth, shiny object, the surface of the computer image is given a simulated reflective quality. Any other objects nearby on the screen are then seen reflected in the surface. And if the surface is curved, then any reflection seen in it will be distorted and appear just the same as if seen in a real curved mirror.

The last stage is to 'light' the image – 'painting' highlights and shadows that show its curvature, just as if the image were a real object seen under a real light.

Surreal images

Imitating ordinary lighting and surface effects gives the illusion of reality, which is often what is required. But the versatility of the computer also enables the artist to produce effects that are impossible in reality. For example, the surface of a shiny sphere could be made to reflect dark as well as light. So any parts of it that reflected a black object would simply disappear.

Solid images

The image can even be viewed in 3-D. Versions of the object as seen from two slightly different

viewpoints are created by the computer, then these are flashed rapidly on to the screen. The viewer

IBM United Kingdom Ltd

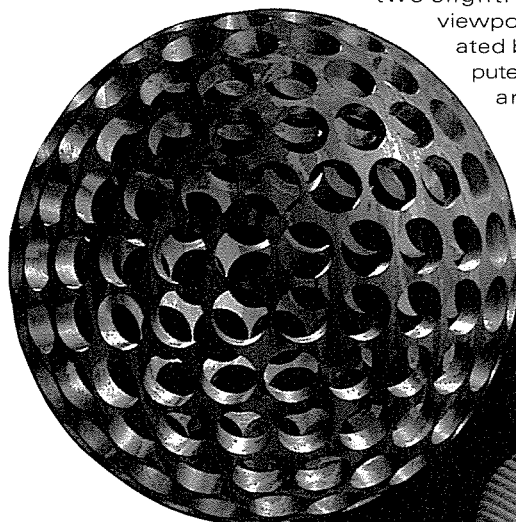
software to produce a variety of sculptural forms on screen. One of the basic rules that Latham works with is called 'branch'. This takes a simple basic form and draws copies of it, radiating from a central point.

Bending and twisting

Another basic instruction is called 'horn'. It draws repeated copies of a basic pattern, while progressively bending, expanding and twisting it, and so on. The result can resemble a ram's horn but is often something much more complicated.

The artist begins to create a structure by playing around on the screen with a 'wireframe' image. This is like a model of the final work, showing shapes as if they were outlined by a

Not a photo of a hollow metal ball with holes through its surface, but a realistic computer-generated image. The object exists only as code in the computer's memory. A 'horn' structure (below right), produced on a computer screen by repeatedly drawing a basic element, while gradually varying its size and position relative to the last one drawn.



wire framework, the surfaces not yet coloured in. The computer can work more quickly with this simplified image when rotating it or zooming towards or away from it.

Wireframe images

All the features of an image on the screen are stored as a series of numbers in the computer's memory. Therefore, when using a simple wireframe image, the computer has less calculating to do when working out what the image should look like from a different angle, or at a different magnification. Showing an image in wireframe form also enables the artist to see relationships among its various parts much more easily.

Colouring the image

A coloured 'solid' view of the same object without much detail can be created next. Then a texture is applied to

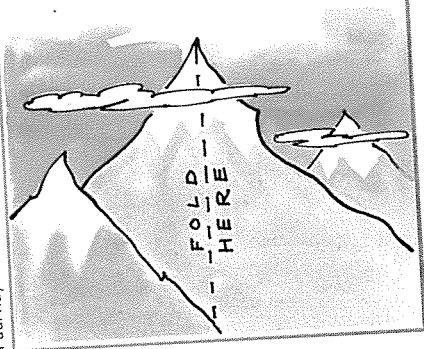
looks at the screen using special spectacles that ensure that the left eye sees one view and the right eye sees the other. The result is that the sculpture has the appearance of a solid, floating in space, instead of a flat image.

Abstract artists long ago discovered the pleasing effects that can be created by applying some rule repetitively. Now the computer helps to speed up the process.

Just amazing!

PAPER MOUNTAIN

IF YOU COULD FOLD A PIECE OF PAPER IN HALF 30 SUCCESSIVE TIMES, THE RESULTING WAD WOULD END UP HIGHER THAN MT. EVEREST.



Paul Raymond



SMART BODIES

NOISE CANCELLING

NAVIGATION

CONCEPT CARS

The dashboard of the car of the future will be packed with computer screens and holographic displays, giving the driver continuous information on the state of the car and helping the driver find the quickest way to his destination. The outside of the car will be more streamlined to improve fuel efficiency.

George Haling/Science Photo Library

Berenguer/Jerrican

BY THE YEAR 2000, CARS will be quieter, cleaner and safer. A whole range of advanced technologies, now being developed, is about to change the face of motoring dramatically.

Metals such as aluminium and steel, which currently make up the bulk of car bodies, will gradually be re-

placed by new materials called composites that are both lightweight and amazingly strong.



Composites

Some motor manufacturers are already building the body panels of new models from a carbon-fibre composite. This material derives its great strength from long, slender

strands of carbon held in place by a plastic matrix.

Even more remarkable is the possibility of cars being made from 'smart' composite materials. These will contain large numbers of tiny sensors that can send out a warning message if some component is damaged or under too much stress. Information from the sensors will travel in the



form of laser light along hair-thin optic fibres to a central, onboard computer. In an instant, the computer will analyse what to do about the problem. The computer may alter the characteristics of the bodyshell to withstand impact or simply flash up a warning.

Quieter cars

One of the drawbacks of composite car bodies is that they tend to vibrate more than steel shells. Normally this would increase the level of noise. But thanks to a new technique known as noise cancellation, future cars may be far quieter.

A noise cancellation system works by detecting sounds through a micro-

Chrysler Corporation



The Plymouth Voyager III is designed to cut down congestion in cities. Out of town it is a large minibus. But by shedding its rear section (above), it turns into a small, easy-to-park mini car.



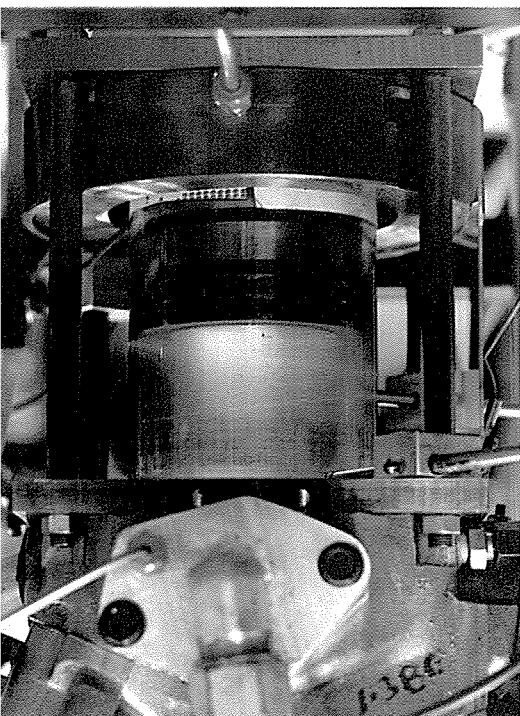
quency booms that are the most annoying. These are passed on to a central processor. The computer works out an identical, but cancelling, boom and generates it using the amplifier in the car's radio.

Engine mounts

Another source of noise inside a car is vibrations in the engine mount. If the engine is held very stiffly by its mount, the car's handling is improved. But this leads to more vibration of the body - so the noise level rises. A mount that is too soft, on the other

This sapphire cylinder allows engineers to see what is going on when petrol is ignited. Sapphire is the only transparent material that can withstand the heat and pressure of an engine.

General Motors Corporation



phone and generating exactly the same sound, but shifted half a wavelength out of step so that it cancels out the original sound.

At Lotus Engineering, researchers have developed an ingenious noise cancellation system that makes use of the car's radio and speakers. Eight tiny microphones pick up the low-fre-

quency booms that are the most annoying. These are passed on to a central processor. The computer works out an identical, but cancelling, boom and generates it using the amplifier in the car's radio.

With air pollution mounting and oil supplies dwindling, more and more cars in the future will be powered by

engines that do not use petrol. General Motors has demonstrated a prototype electric car that can accelerate from 0 to 96 km/h in just eight seconds and reach a top of speed of about 160 km/h. Called the Impact, it has a streamlined, glass-fibre body and special tyres that can be inflated to twice the pressure of normal car tyres. Its sleek shape allows the Impact to cut easily through the air, while its high-pressure tyres reduce rolling resistance. Microprocessors control the engine to give maximum efficiency from one instant to the next.

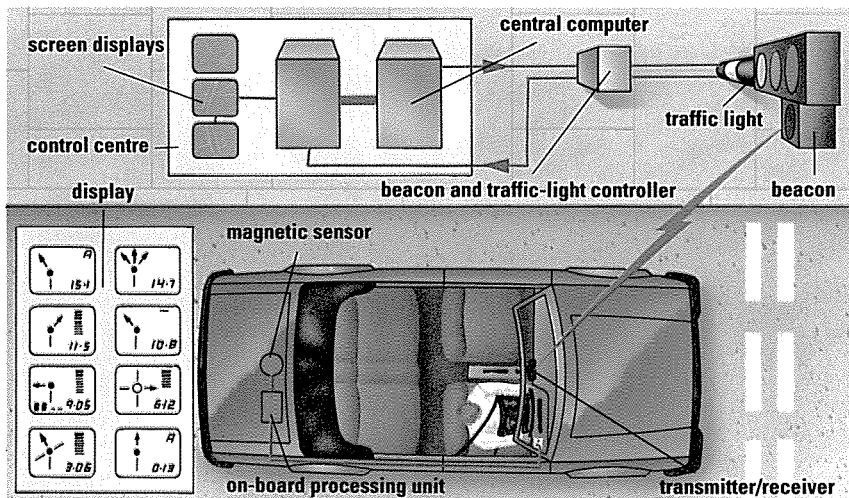
Chrysler Corporation

FOUR-WHEEL STEERING

Steering with all four wheels, a feature of some new cars, leads to a dramatic improvement in handling. The movement of the two sets of wheels is determined by a computer linked to a hydraulic steering system. At speeds over about 32 km/h, the computer ensures that all four wheels turn in the same direction. As a result, when cornering, the rear wheels help the car to turn rather than being simply dragged around the curve. This adds greatly to the stability. At lower speeds, however, the computer causes the rear wheels to turn the opposite way to the front wheels. This reduces the turning circle, making the car easier to park and more manoeuvrable about town.

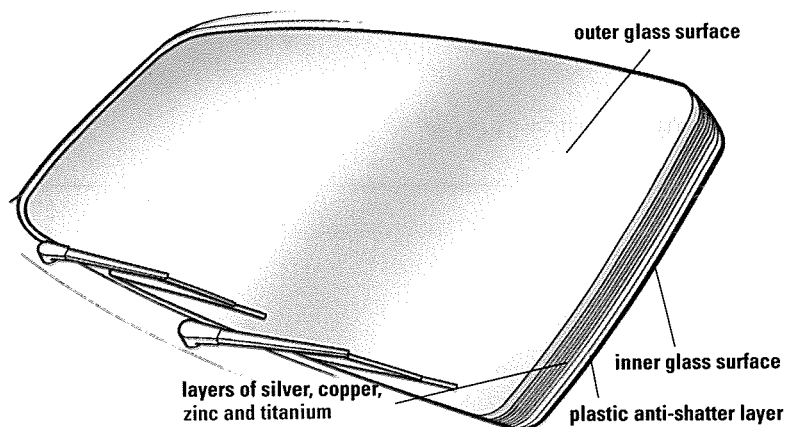
Despite its impressive performance, the Impact breaks no new ground in battery technology. In an ordinary car, a single 12-volt lead-acid battery provides the current needed to start the engine. The Impact, by contrast, uses 32 10-volt lead-acid batteries to provide continuous cur-

Autoguide is a computerized car navigation system. Once the driver has keyed in his destination, the car navigates by magnetic sensor and data fed from infra red beacons



Mark Franklin





New windscreens cut down the amount of the Sun's heat that is passed into the car. Sungate glass incorporates thin layers of metal to reflect the heat, while allowing light through.

apparent motion, measured by the revolutions of the wheels and the compass bearing, fails to match the pattern of streets – errors tend to build up in the system on long trips.

Satellite fixing

Such problems disappear when the car navigation system uses data from navigation satellites in Earth orbit. By picking up signals simultaneously from two or more satellites, the car's position is fixed, with accuracy, automatically.

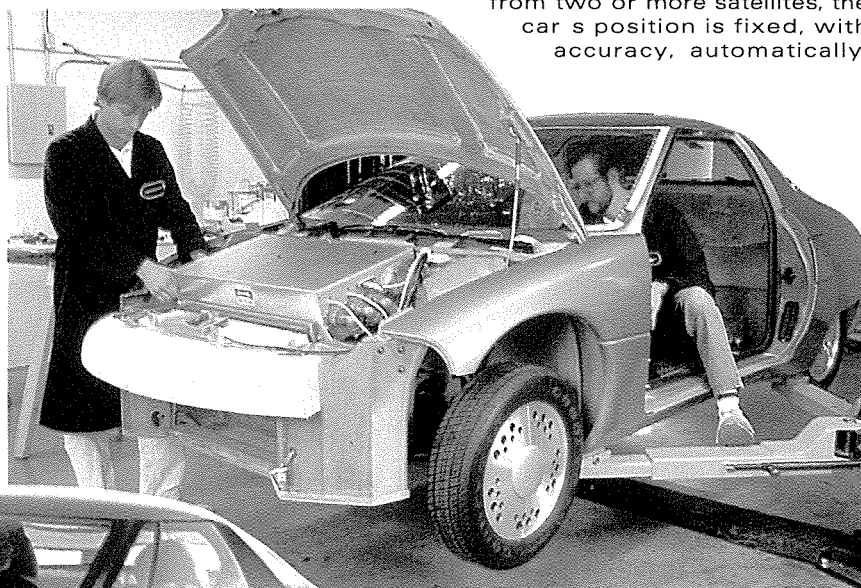
Mark Franklin

rent to drive the wheels. These batteries are very heavy and allow the Impact a range of about 200 km between rechargings. In the near future, a new type of battery, based on sodium and sulphur, is expected to double the range of electric cars while weighing only half as much (see ENERGY AND RESOURCES p129-130).

Shortest route

One of the biggest breakthroughs in road travel will be brought about by in-car navigation systems. By informing the driver of the shortest route to his or her destination, avoiding heavily-congested roads ahead, such systems will help save fuel and make journey times shorter.

Several companies already sell car navigation



Gamma/Frank Spooner Pictures



General Motors (Europe)

Early navigation satellites were not accurate enough to pinpoint a car's position to the nearest street or intersection. But the United States Global Positioning System's 24 satellites give continuous coverage anywhere on Earth and are capable of fixing a car's position to within 100 metres, making satellite navigation for cars a reality.

General Motors' Impact is an electric car whose speed and acceleration compare well with petrol-driven vehicles. A huge battery (above right) is mounted under the bonnet but can only take the car 200 km.

systems based on optical discs, similar to compact discs. These work by storing maps and following the car's progress. The trouble is that the driver must enter his current position, which he may not always know. Also, the device may get lost when the car's

The hubless wheel gives better steering, suspension and braking. On a motorbike – where it is driven by a chain – it works well. But on a car no satisfactory way has yet been found to send power to the wheel.

Just amazing!

CAR TALK

SOME CARS CAN UNDERSTAND ENGLISH. VOICE RECOGNITION CIRCUITS ON SOME SYSTEMS RESPOND TO THE DRIVER'S SHOUTED COMMANDS.

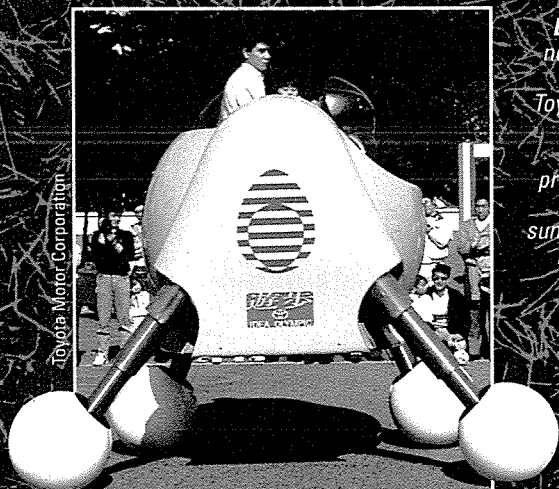


Paul Raymond





VIEW OFF THE DRAWING BOARD



Toyota Motor Corporation

Energy efficiency is not lost on Japanese car manufacturers. Toyota's aerodynamic TES K3 is solar powered. The prototype works well, but the world is not sunny enough to see it in mass production.

Toyota is a car manufacturer but at the 1989 Tokyo Ideas Olympics one of its employees came up with this walking machine. It won a bronze medal.

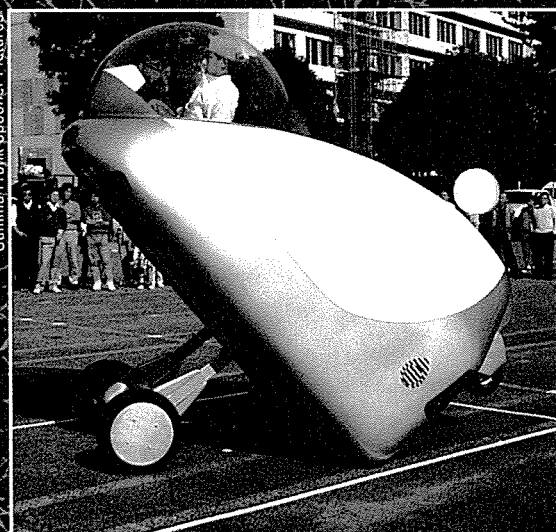


Sauter & Lierjean

Subaru's Jo-Car at the 1987 Tokyo Motor Show. The profile and wheel housings are very aerodynamic but the interior (left) reveals conventional controls.

Gamma/Frank Spooner Pictures

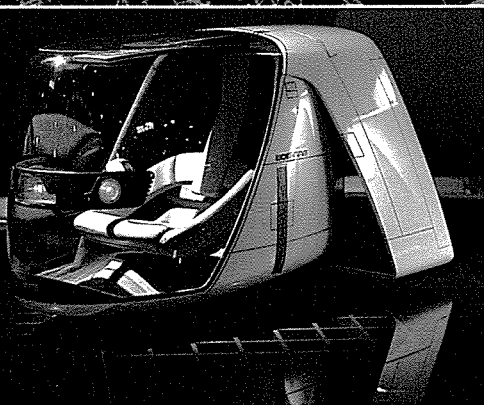
Great visibility, easy to park and pretty aerodynamic when the front wheels are retracted, the 'Rolling Sky Car' won the silver medal at the Tokyo Ideas Olympics.



The ultimate town car with all-around visibility, ultra-modern comfort and aerofoil pylons supporting the rear wheels in case you want to go faster.

The science-fiction influence is obvious in the Reva, but few people would want to buy what looks like a glorified dodgem.

Gomier & Lierjean



Toyota Motor Corporation

Toyota Motor Corporation

Four wheels each driven by an independent motor gives the 'Kinton' - or 'Relax' vehicle - total manoeuvrability. It took the gold at the Tokyo Ideas Olympics.



Sauter & Lierjean



How a Maglev Train Works

TRAINS OF THE FUTURE WILL speed along quietly and smoothly at over 500 km/h — without ever touching the track. They will be kept aloft by a process called magnetic levitation, or Maglev, and be powered by a special kind of electric motor.

Magnetic levitation is based on the principle that like magnetic poles repel each other and unlike poles attract. Two different Maglev systems have been developed from this basic principle.

Magnetic attraction

In a magnetic attraction system, the train's electromagnets are positioned so that they lie below the track. When energized, the magnets are attracted towards the track magnets and cause the train to rise. Sensors measure the air gap and send signals to a control system, ensuring that the magnets hang about 10 mm apart.

In Japan, trials are going ahead of a second system known as electrodynamic suspension (EDS). This uses electromagnets on the train and a series of coils on the track. When activated, the onboard magnets set up opposing magnetic fields to those in the track coils, so pushing the train away from the track.

Japan's experimental train, named simply Maglev, rides on rubber tyres at speeds of up to 100 km/h. Then the magnetic levitation system takes over. The onboard electromagnets sit at the bottom of the train, while a pair of relatively low temperature superconducting coils in the track, with a liquid helium cooling system, become superconducting. In other words, they offer virtually no resistance to an electric current. This means the air can't get in and the magnets have been energized, they require hardly any power to maintain them at full strength.

Superconducting magnets are also very strong. Those aboard the Maglev lift the train 10 cm off the

Magnets, suspended from a chassis of a train, are pushed towards track magnets, causing it to hover.

magnetic shielding

passenger compartment

superconducting electromagnet

concrete base

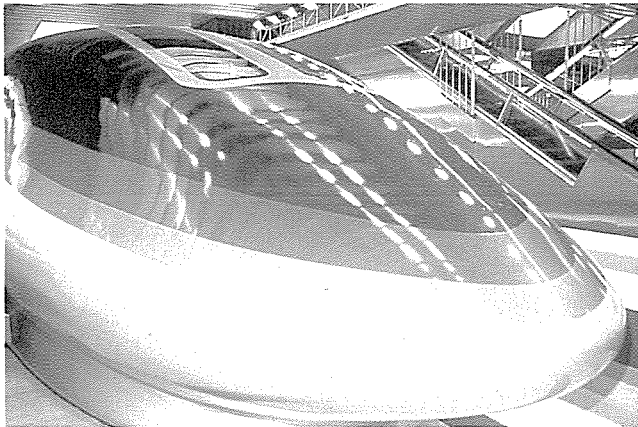
aluminium guide rail lifts train

A Maglev train link between Japan's two largest cities — Tokyo and Osaka — is being planned for the 21st century. It will carry passengers at over 8 kilometres a minute.



MAGLEV TRAINS





The linear motor express, which reached speeds of 500 km/h during test trials, is powered by a chain of electromagnets. Electric currents flow through a set of coils in sequence, creating a moving magnetic field that can pull a heavy vehicle.

track. In Japan, where small earthquakes can occasionally shift the track by up to 2 cm, this is an important safety factor. The liquid helium system is bulky, though, and requires an elaborate refrigeration plant.

Linear induction

Once off the ground, Maglev is propelled forward by a special kind of electromagnetic motor called a linear induction motor. A linear motor makes metal objects move along in a straight line. It does this using a chain of electromagnets, or coils. Changing electric currents flow through the coils in sequence, creating a moving magnetic field in the region above. This moving magnetic field carries any metal object, such as a Maglev train, along as if it were caught in a fast-flowing river.

Birmingham International Airport, UK, has a Maglev train link to transport air passengers from the central railway station to the airport terminals.

In tests, Japan's Maglev has already reached a speed of 400 km/h on a 6 km-long stretch of track at Miyazaki. A longer section of Maglev track, 43 km long, is being built in Yamanashi Prefecture just south of Tokyo.

Since 1984, West Germany has also been developing a magnetic levitation system, known as Transrapid.



Birmingham International Airport plc

The German train uses conventional instead of superconducting magnets, lifting it just 1 cm above the track. The other difference is that Transrapid sits on top of its guideway, straddling it with magnets, whereas the Japanese Maglev runs inside a U-shaped track.

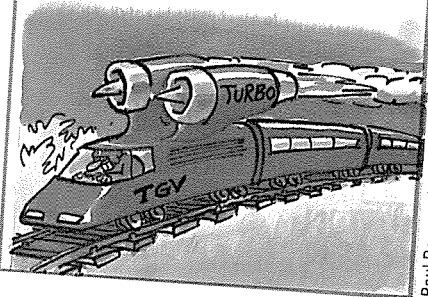
Health hazard

One big advantage of the German train is that its onboard magnets are placed further from the passengers. As well as affecting electronic watches and personal stereos, magnetic fields above a certain strength may be dangerous to human health. Japanese engineers, however, believe that the powerful fields aboard Maglev can be screened out.

Just amazing!

VITE! VITE!

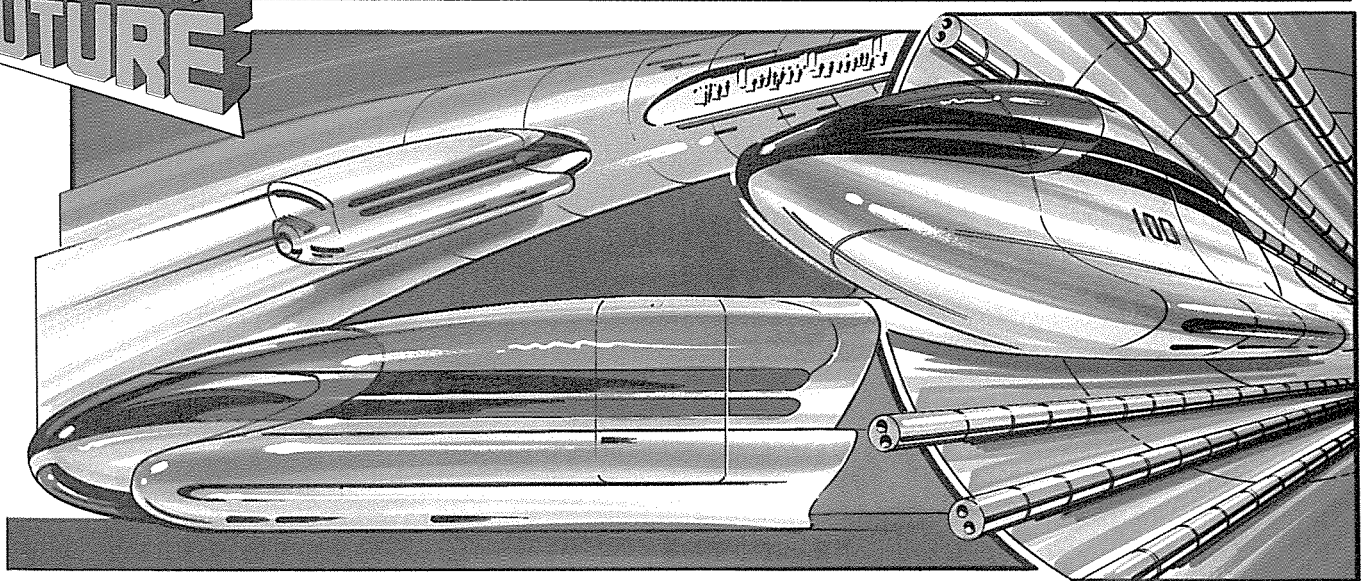
IN MAY 1990 FRANCE'S NEWEST TGV (TRAIN A GRANDE VITESSE) REACHED A RECORD 515 KM/H – HALF THE SPEED OF A PASSENGER JET!



Paul Raymond

INTO THE FUTURE

TUBECRAFT



Joe Lawrence

▲ Researchers in the United States have suggested building 'tubecraft' that could streak through underground tunnels at speeds of up to 22,000 km/h.

▲ A tubecraft might look like a streamlined train without wheels or an aircraft without wings. It would be propelled by electromagnetism.

▲ Super-conducting cables would generate opposing magnetic fields so that the 100-passenger craft would float in the middle of the tunnel.



-  FLEXIBLE TOOLS
-  PRODUCTION DATA
-  NUCLEAR ROBOTS

THE FUTURE FACTORY

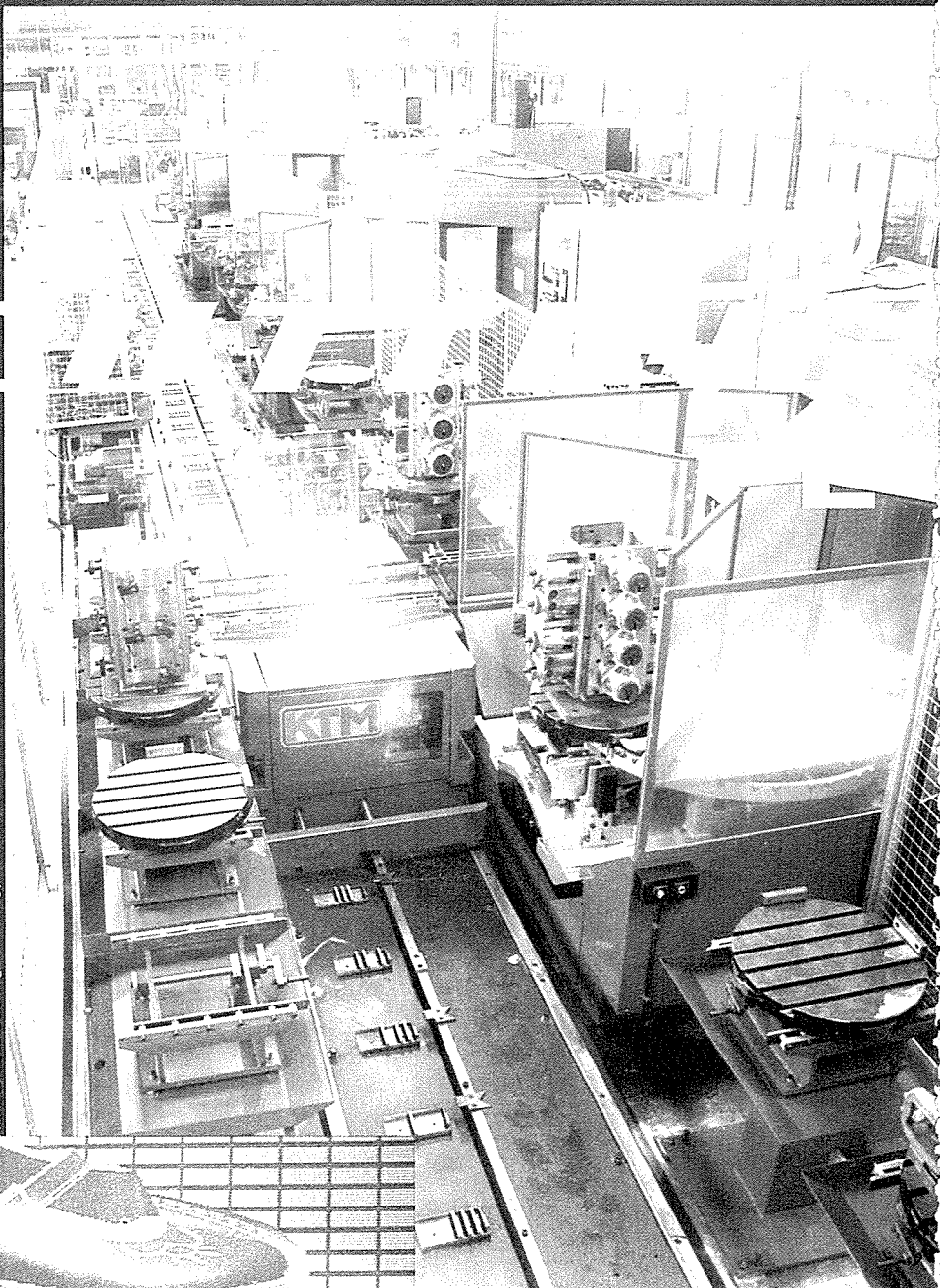
THE FACTORY OF THE future will be one giant collection of automatic tools and equipment, controlled by a team of designers and production engineers.

What is making this revolution possible is the development of flexible manufacturing technology. In the past, production lines have been set up with each unit producing one particular component, or putting one particular component in place. But now, flexible manufacturing technology is introducing machines that will make any component required, then assemble the components in any way. The result is production lines that are capable of producing an enormous variety of products.

Profile milling

One of the first uses of flexible manufacturing technology was making the wings for the European Airbus. Formerly, wings were made out of separate, smaller sized panels which were then shaped and riveted

Flexible Manufacturing Technology



Jerry Mason/New Scientist/SPL

together. It took a large work force to do this. The jointing and riveting of the wings also caused severe engineering problems. Each panel edge and each rivet was a source of drag, cutting down the efficiency of the plane as it forced its way through the air.

What is more, the European Airbus, like most modern aeroplane designs, is not a single plane but a family of aircraft. Using conventional technology, each time a wing for a different member of the Airbus family was made, the production line would

CAD - Computer Aided Design has many applications in manufacturing technology - ranging from designing prototypes of cars and trains to creating a range of shoe styles.

A host computer controls the three machining centres, which are linked by a rail-guided Roevatran truck. Work is transported between the machining centres and pallet stands.

have to retool - an expensive process. But using the flexible manufacturing technology, the entire wing skin is cut in one piece and any one of the wing skins for any member of the Airbus family - or any constructional part of an aircraft - can be cut simply by reprogramming the machine.

The profile milling machine used to make the Airbus's wings has a flat bed 66 metres long and 3.5 metres wide. Two massive gantries straddle this bed. Each carries a 80 horsepower,



five-axis cutting head that can spin at up to 10,000 revolutions a minute. Many different types of cutters are used and on some machines they can be changed automatically. The gantries weigh over 35 tonnes and the whole milling machine weighs 530 tonnes.

Huge sheets – or billets – of light aero-alloy are fixed to the machine table by a vacuum holding unit. The

Smaller cutting machines can offer even greater flexibility than these huge profile millers. One installed in a valve factory in northern England, UK, can produce any one of 2,400 different components at random without

anyone touching the machine. And each component can be checked by a laser system to ensure that it measures up exactly to specifications.

The success of these machines depends, of course, on computer control or DNC – direct numerical control – and the experts who have developed them have found that it is possible to integrate it into the whole of the design and manufacturing process. Already, industrial designers use CAD – computer aided design – for a large range of products.

Design on screen

The designers can draw up the design of a new product on a computer screen using a mouse, a light pen or graphics pad, then rotate it to see it from any direction. They can see on the screen precisely how different components fit together. And using sophisticated simulation programs, they can check how fluid flows through a valve or air flows over a car body before even beginning to make a prototype version.

Once the design has been proven, the data generated by CAD can be used to control the DNC machinery that makes a prototype – then, later,



British United Shoe Machinery

Shoe-making for the mass-market is today largely performed by Flexible Manufacturing Systems that can be adapted rapidly to changing styles. Here an Automatic Upper Roughing Machine is used.

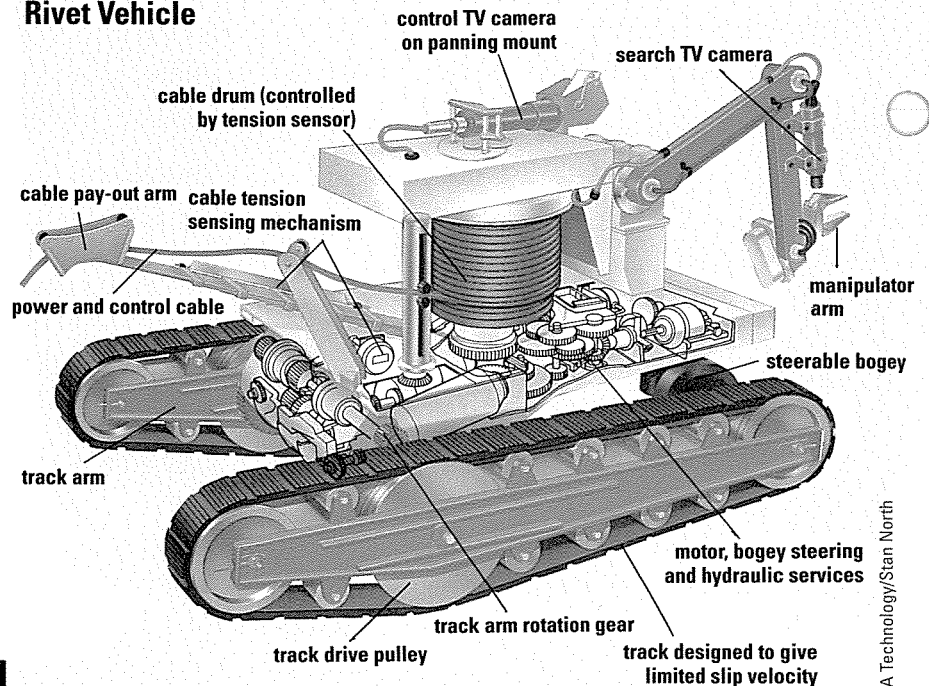
A Remote Inspection Vehicle, which was designed primarily for essential damage-control following a reactor incident in a nuclear plant. It can also be used in other hostile environments.

giant cutters then machine away up to 90 per cent of the billet to leave the thin, delicate, precisely shaped wing skin up to 23 metres long. The massive volume of waste – or swarf – created is vacuumed away and recycled to make fresh billets.

The profiler is long enough to carry three wing panels so that the gantries and their cutting heads can work on two, independently, at any one time, while a third completed wing panel can be removed and replaced with a fresh, unmachined, light alloy billet.

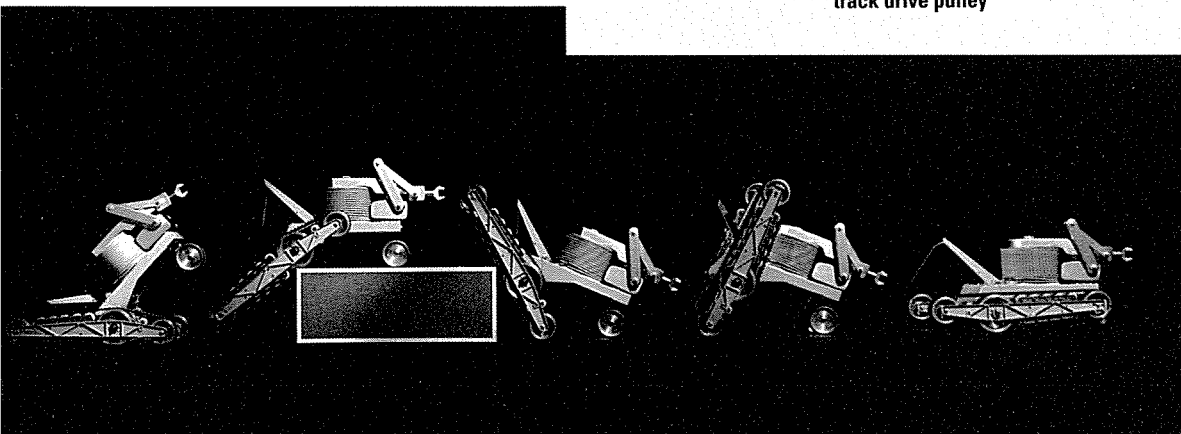
AEA Technology

Rivet Vehicle



AEA Technology/Stan North

A RIVET (Remote Inspection Vehicle) demonstrating its manoeuvrability. It can negotiate narrow passages, closed doors and stairs of varying steepness. If boxed-in or accidentally inverted it can find its way out unaided.

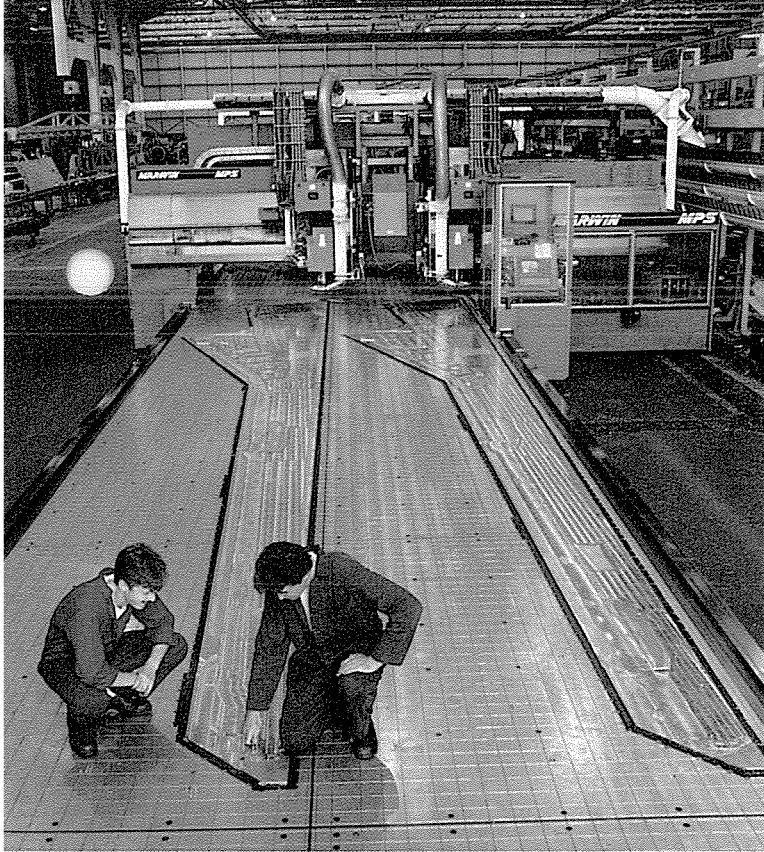


The wings for the largest aircraft built in Europe – the Airbus – are machined on the largest machine tool in Europe. The 530 tonne purpose-built machine is 66 metres long – the length of three cricket pitches – and 3.5 metres wide.

components along the production line and the robot arms that fit the pieces together. Remote sensors can check cutting bits and the efficiency of each machine as well as running quality control checks on every item at every stage of the production line. All this data can be fed back to a central computer where the whole manufacturing process can be monitored.

In addition, business data can be fed into the system – sales figures and forecasts, production costs, profit margins and financial data – giving

AEA Technology



British Aerospace

makes the product itself. This process is known as CAM – computer aided manufacture.

But the use of computers in factory production lines can go much further than this. Computers can also be used to control the conveyor belts and unmanned vehicles that carry the

Materials in the nuclear industry normally need to be handled by remote control. The method shown here is known as adjacent handling.



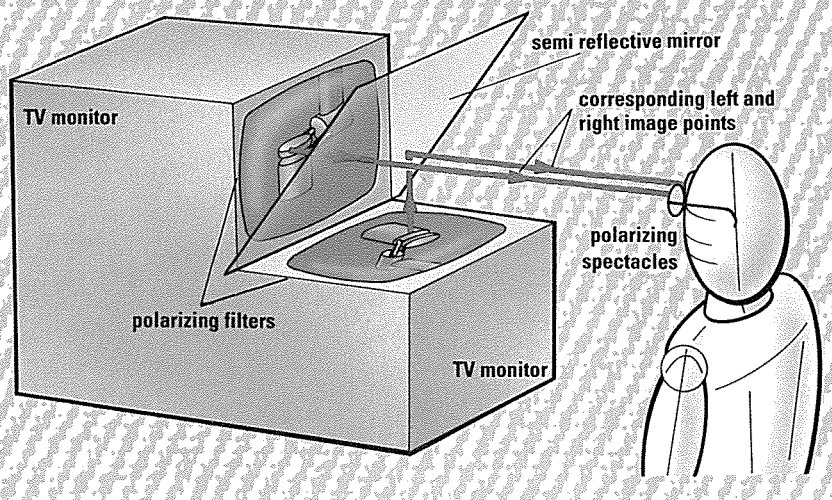
3D TELEVISION

Conventional television, only showing two dimensions, is of little use when performing delicate tasks deep within a nuclear reactor.

To overcome this, scientists at the UK Atomic Energy Authority at Harwell have developed 3D television. Two cameras placed side-by-side two eyes' width apart are mounted on a remote inspection vehicle. The pictures are then relayed to two television monitors mounted at right angles to each other. One faces the operator directly, the other lies screen up in front of it. The screens are covered with polarizing fil-

ters, polarizing one image vertically, the other horizontally.

The two images are superimposed using a semi-reflective mirror placed at 45° between them. The operator views the combined image wearing special glasses with a vertical polarizing filter in one lens and a horizontal polarizing filter in the other – so the left eye only gets the image from the monitor connected to the left camera and the right eye only gets the image from the monitor connected to the right camera. The operator can then see and judge movements more accurately.



AEA Technology/Mark Franklin

what is becoming known as CIM – computer integrated manufacture.

One example of this is a factory in Britain's Midlands, British United Shoe Machinery Co, that manufactures shoe-making machinery. Shoes all have the same basic components – leather, synthetic materials like rubber and metal for toe caps, heel guards and the eyes of lace holes. But there are an infinite number of different shoe designs. Some lines sell well, others badly. Different types sell better in winter than in the summer. Colours and styles change with fashion. Overall demand depends on the state of the economy, interest rates, wage settlements, and the rate of inflation; market trends and export orders are affected by currency fluctuations.



Forecasting trends

Using flexible manufacturing technology and computer integrated manufacturing, it is possible to produce any type of shoe in any number to fulfil any order. But business computer systems can also forecast forthcoming trends and when designers develop new designs, using CAD, these can be programmed into the system's library where they can be stored until the demand in the market is ready for them.

Once the computers are linked the whole system works automatically, without human intervention on the shop floor. And without expensive re-



tooling, stock piling and the over-production of unpopular lines, the factory can be run at maximum profits while keeping the cost of the products to the customer to a minimum.



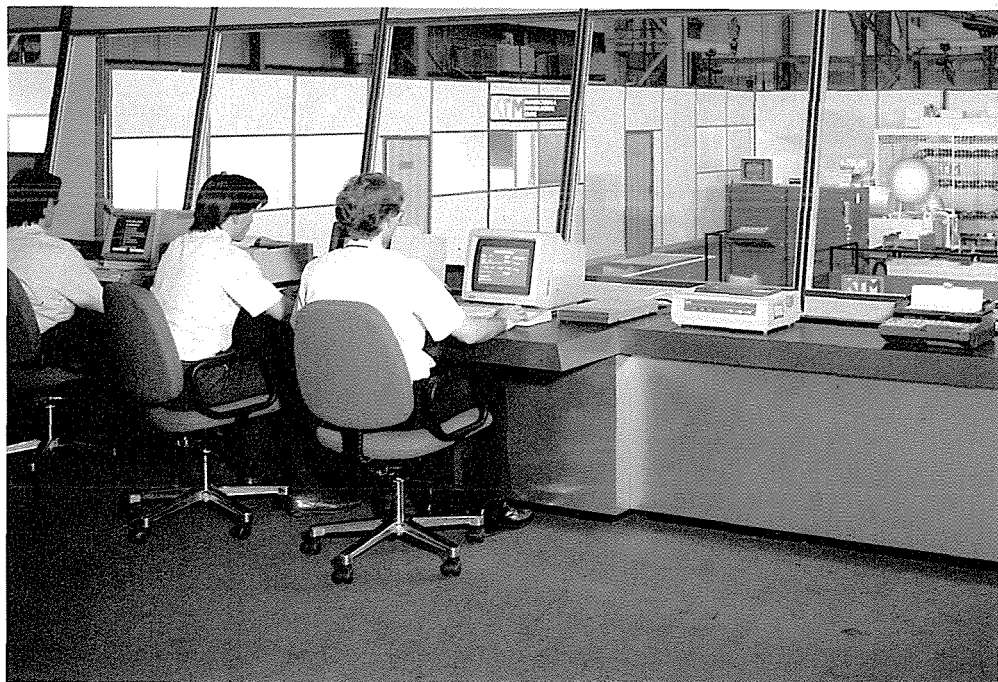
Remote handling

In some industries tools must be handled remotely because the materials concerned are too dangerous to touch. Nowhere is this more necessary than in the nuclear industry.

Handling materials that are only mildly radioactive can be done in a glove box. This is a sealed box with a pair of long, heavy-duty gloves sealed into holes in a thick glass window. The operator can put his arms into the gloves from outside and handle radioactive material without it ever being exposed to the atmosphere.

Also in use is a method known as adjacent handling. Typically in this method the operator views his work through a shielding window and uses a pair of mechanically linked master-slave manipulators (MSMs).

Flexible Manufacturing Technology



The control room is an integral part of a computerized flexible manufacturing system. The main computer controls the scheduling of work through the system and supervises the machining centres.

chines carry robot arms so that they can perform all sorts of functions deep within a nuclear power station. They may also be used in other areas dangerous to humans

The robot arm on these vehicles is remotely controlled by an operator outside the radioactive area, who uses 3D television (see box on page 117) for accurate scale and perspective. Thus industrial robotic developments are combined with the skill of a human operator. By using tele-robots and remote inspection vehicles the element of human fatigue in causing error or accident is reduced and risk to personnel is minimized.



Massey-Ferguson

Automatic guided vehicles (AGVs) are used to transport components in warehouses and factories. They can be wire-guided by wires beneath the factory floor or laser-guided.

Deeper within the sealed areas of a nuclear power station, however, robot arms are used. These are controlled by outside operators and are often suspended from gantries so they can move about the sealed area. However, their movement is limited and they cannot cope with unforeseen acci-

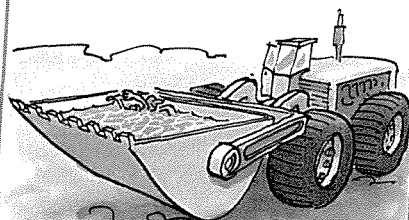
dents or the huge range of problems that crop up when decommissioning a nuclear power station.

Walking machines and remote inspection vehicles have been developed, so that equipment in sealed areas can be checked and adjusted. Another use of the machines is their ability to scan and monitor hot spots on a surface and to successively decontaminate the area using an electrochemical method. They have been designed to climb stairs and negotiate difficult terrain even if the floor is cracked or damaged. These ma-

Just amazing!

DIGGING DEEP

THE LARGEST EXCAVATOR IN THE WORLD, MADE IN HAMBACH, GERMANY, CAN CLEAR 200,000 SOM OF EARTH PER DAY - ENOUGH TO FILL 150 OLYMPIC SWIMMING POOLS.



Paul Raymond



- Q HEAT SENSORS
- Q VOICE CONTROLS
- Q INTEGRATED OFFICES

A prototype house where all systems and appliances from heating and security to TV and coffee machine are operated via a networked computer system.

BUILDING BRAINS

FAR FROM SHELTERING us from the weather, new 'intelligent' buildings are evolving to take care of our every requirement at home and in the workplace.

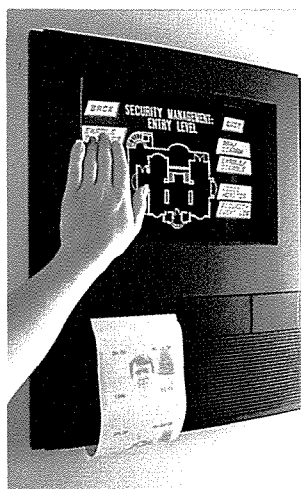
Intelligent buildings are constructed around a computerized central control system that operates such amenities as lighting, heating, communications, entertainment and security. Computers control and co-ordinate all of these functions at the touch of a button on either a fixed console or a remote control device.



Energy monitor

A central computer can even be programmed to act automatically so that, for example, as it gets dark outside, the lighting level gradually increases inside and when people leave a room the computer turns off the lights – making light switches obsolete and saving energy.

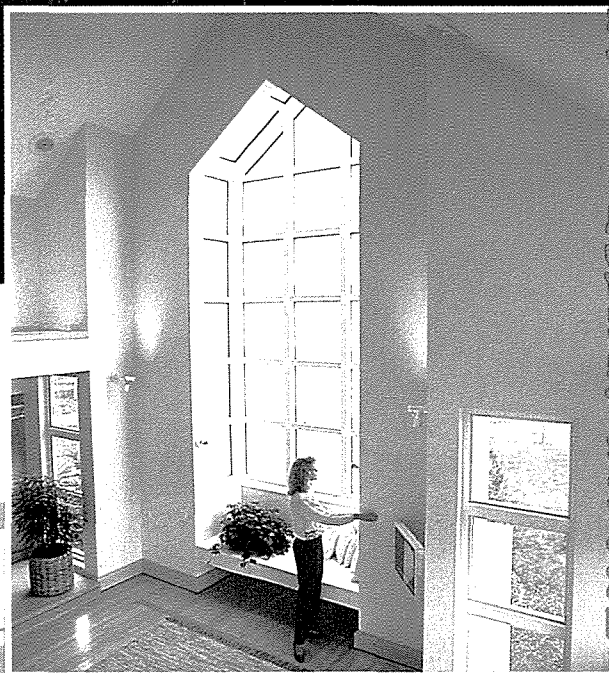
Heating can be controlled similarly. Sensors at strategic points will detect when temperatures vary from pre-set values and adjust the heating system accordingly for individual rooms. For greater efficiency the system can be programmed to switch room heaters



off when a room is empty.

The new houses will be cost effective in other ways too. If the washing machine can 'communicate' with the electricity meter, it will wait until the electricity supply is at its cheapest to wash your clothes.

The central computer could even be activated by voice commands. There are already prototype buildings in the United States, where pre-set programmes can be operated by



A liquid-crystal window is white in its normal state – allowing light in while providing privacy. At the touch of a button, a current runs through the window to realign the crystals and turn the window transparent. Commands for such functions are sent to the central computer via touch-control screens (left).

Jerrican

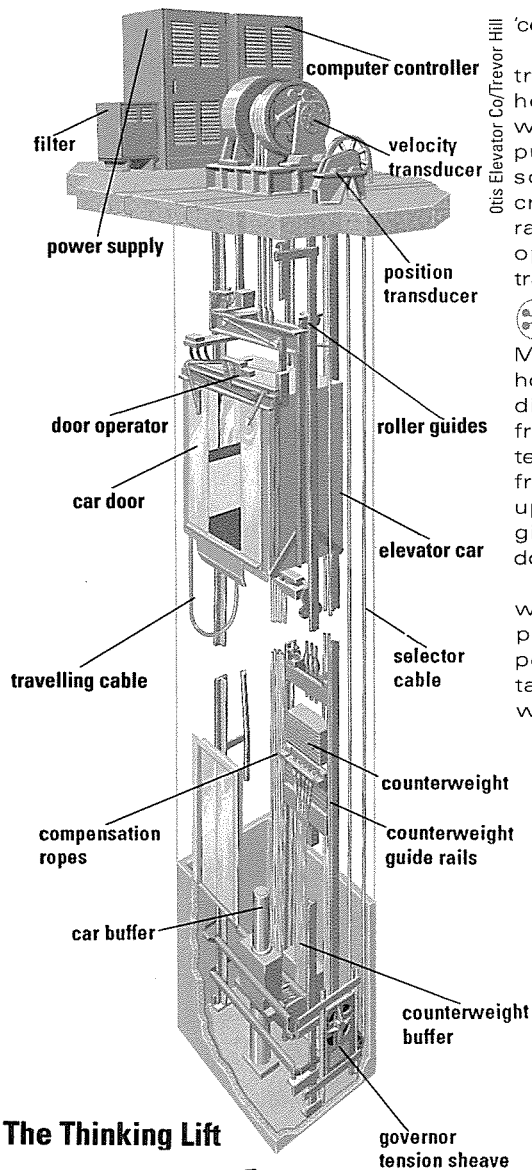
vocal instructions. For example, saying aloud 'privacy mode' will prompt the computer to lower window blinds and lighting levels, the words 'evening party' will bring on spot lights and start music playing on the stereo.



Burglar alarm

The integrated building concept will first become accepted through home entertainment equipment. Already many people are familiar with programming video recorders to





Otis Elevator Co/Trevor Hill

'communicate' with their televisions.

Communication between all electric systems and appliances in the home will mean that, for example, while watching television, the computer will flash messages on to the screen to tell you that your microwave dinner is ready; or that it is raining and the upstairs windows are open; or that security cameras are tracking an intruder in the garden.



Helping the disabled

Many functions of an integrated home will be especially useful for the disabled. For example, a picture of friends arriving will be relayed on the television screen from cameras at the front door. The host, without getting up, will be able to press a button or give a vocal command to open the door and let in the guests.

In the office an integrated system will, for example, flash important telephone or fax messages on to a person's VDU screen while they are taking another call and inform them when a client has arrived in reception.

Advanced gearless elevator systems in high-rise offices and hotels can now 'anticipate' passenger demands. Their computer memories monitor and 'learn' traffic patterns. For example, on Monday morning the system will check data from ten previous Mondays. It will notice that the rush hour on Mondays is later than on other days and will assign cars to certain floors at times when they should be most needed. Communication between cars also ensures they do not all respond to the same calls.

Just amazing!

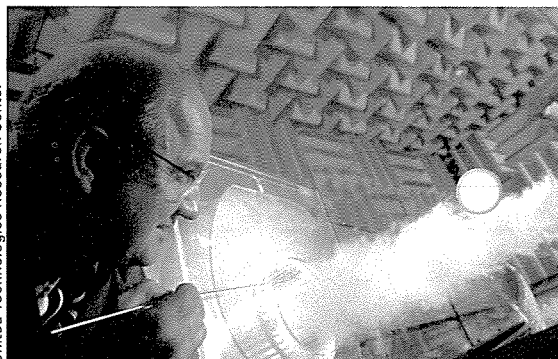
GOING UP

OTIS — THE WORLD'S LARGEST ELEVATOR COMPANY — CARRIES OVER 64 MILLION PEOPLE DAILY IN ITS ELEVATORS — MORE THAN THE ENTIRE POPULATION OF ITALY.



Paul Raymonde

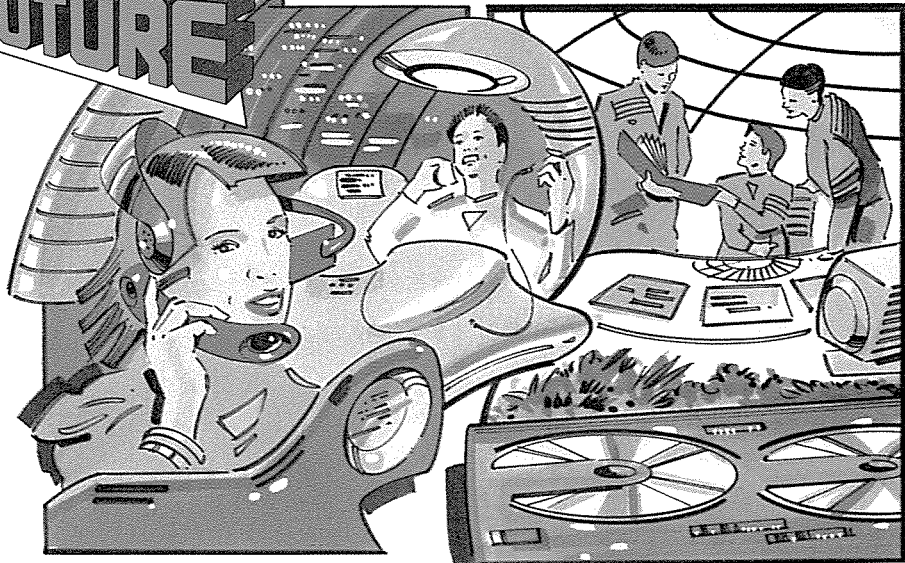
An engineer substitutes smoke for air to study the complex flow through an air-conditioner. All such building systems will be refined to provide maximum efficiency in the future.



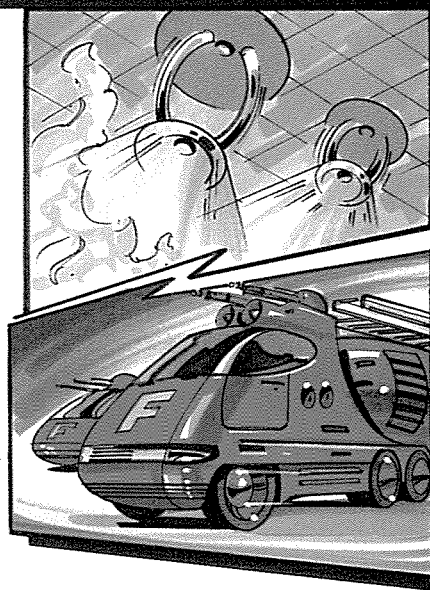
United Technologies Research Center

The Thinking Lift

INTO THE FUTURE



STAFF BENEFITS



▲ Built-in office computer systems will control temperature and humidity and will boost negative ions in the air supply to promote a feeling of well-being in staff.

▲ Even on the dullest days artificial light sources will imitate the natural sunlight of a beautiful day. Inspiring background music will be available on request.

▲ In the event of fire, recorded voices will calmly direct workers to safety while sprinklers are activated and fire services alerted automatically.

Joe Lawrence



- Q GAMES THEORY
- Q DRAG REDUCTION
- Q MULTIHULLS

RACING YACHTS

Yachts compete within a framework of regulations and sometimes with handicaps. This 5.5-metre skiff was photographed at the Grand Prix off Perth, Western Australia, in 1987.

The mainsail (single-coloured sails below) provides much of a boat's power and balances its helm. In use for the duration of a race, the mainsail must be very tough.



Leo Mason/Split Second

WHEN STARS AND STRIPES swept across the finishing line in 1987 to win the prestigious America's Cup, a new era in the development of hi-tech racing yachts began. For the first time, computers had been used extensively to calculate the ideal shape for a competition yacht's sails, hull, and keel.

Four years earlier, the United States had been stunned by the loss of the America's Cup to *Australia II* in the final held off Newport, Rhode Island, USA. The success of *Australia II* was due largely to a revolutionary new keel design. Instead of the simple upright keel of an ordinary yacht, the one fitted to *Australia II* had two winglets (small wings) at its base. This was kept a closely guarded secret until the race was over.

A yacht's keel has two main purposes. First, it helps to turn sideways wind pressure on the sails into forward movement of the boat. Second, it can be weighted so that it acts as a ballast to help prevent the boat from tipping over when the wind blows sideways on the sails. On a 12-metre vessel used in the America's Cup, lead ballast accounts for 70 to 80 per cent of the boat's total weight. A keel with winglets also serves as a hydrofoil, providing lift or pulling the craft down.

Winglets

Using a set of specially written programmes running on a minicomputer, the designers of *Stars and Stripes* made improvements to the Australian winged keel idea. These included giving the keel more taper from front to back, thicker keel-tip

sections to make the keel more streamlined, and wider winglets.

The computer also helped to test various sizes and shapes of sails. Traditionally, sail plans were drawn by hand and the final, full-scale version laid out in a large open loft. For *Stars and Stripes* the sails were designed using a computer.

Weather forecasts

At each stage, the performance of the keel, hull, and sails was modelled by the computer under a variety of race conditions. The designers took account of the likely state of the sea and weather off Perth, Australia, where the competition would be held. They also found out as much as possible about the opposition's boats. A program using mathematics known as games theory then predicted what was the most likely design to win over a variety of wind strengths and sea conditions.

In the future, computers will play an even greater role in the design and testing of advanced sailing ships.



Since this will avoid the expense of building many real prototypes, designers will have much more freedom to experiment with various new shapes and configurations.

Riblets

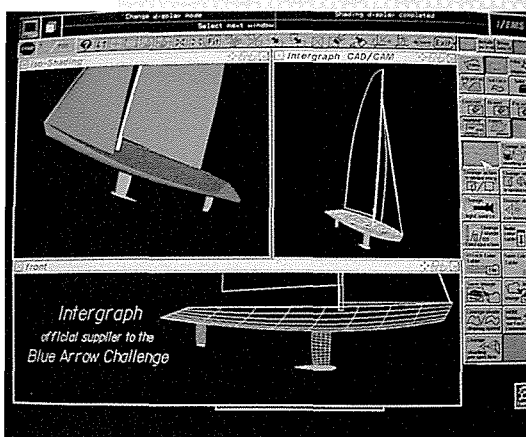
Friction between hull and water is one of the main factors that slows down a racing yacht. Many coatings have been developed to reduce this drag, but few have proved to be any better than a perfectly clean, polished, painted surface. One that is superior, however, is an experimental thin, self-adhesive, vinyl film developed by the 3M Company for aircraft.

The 3M material contains microscopic parallel grooves called riblets. These smooth the flow of passing air or water by channelling the fluid along streamlines. First used on the hull of *Stars and Stripes*, this new coating is thought to have reduced friction by up to 4 per cent.

There are about 950 classes of racing yachts, from ocean-going giants costing millions of pounds to the Optimist class of dinghy, popular with children. Some of the fastest classes of sailing boats are multihulls.

A catamaran has two hulls, while a trimaran has a central hull with small hulls on either side. The main advan-

DESIGNING A RACE-WINNING YACHT



Today, computers are used to design and test many aspects of racing yachts. Understanding the stresses of flying sails, for example, helps to design sails that hold their racing shape better.

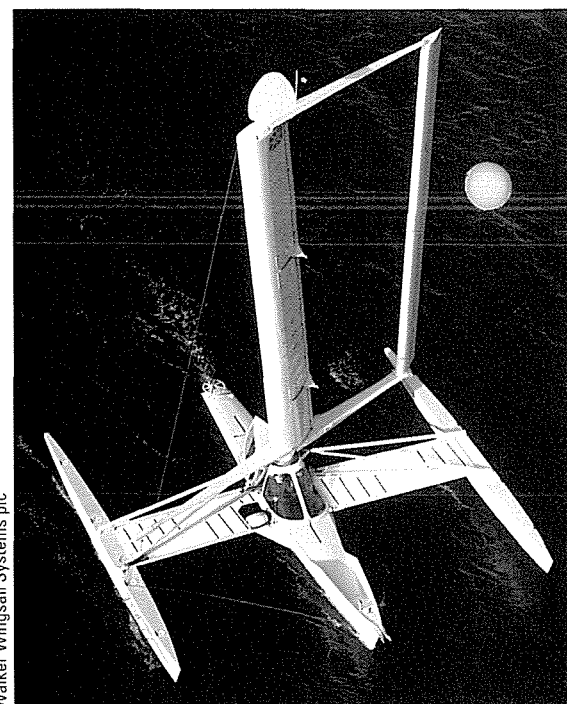
In recent years the materials used to build racing yachts have changed also. Aluminium and wood hulls are being replaced by laboratory produced fibre reinforced plastics (FRPs). FRPs, or advanced composites, are combinations of resins and fibre reinforcements. Fibres – of, for example, carbon, aramid,

polymer or combinations of these – provide the base material and resins hold the fibres in place, protect them from damage and help to spread force between fibres. The end product is lighter, stiffer and stronger than its traditional counterparts and is used in the construction of aircraft, road vehicles and



rescue boats as well as racing yachts.

An FRP half-hull (above) is coated with resin. The resin becomes liquid when heated to 75° C and must be pressed into the hull and worked smooth before it cools and sets.

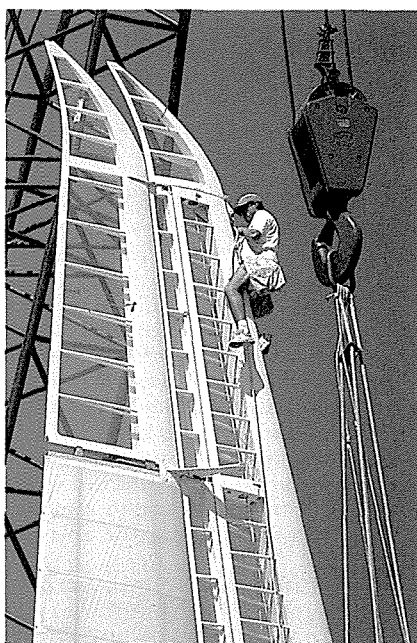


Walker Wingsail Systems pic

Rigid sails, as on this racing trimaran, may be the technology of the future. The craft is operable by one person with no sail rigging. A computer translates pilot commands into flap and tailfin angles according to wind, boat speed and direction.

'wingsails' have flaps, air-directing slats, and motorized actuators to move them, as on an aircraft wing.

Mounted on the hull by a large ball-joint, each can be controlled manually or by a microcomputer fed with data on the direction and speed of the boat by sensors placed around the hull.



Intergraph/N Rains/Pickthall Picture Library

N Rains/Pickthall Picture Library

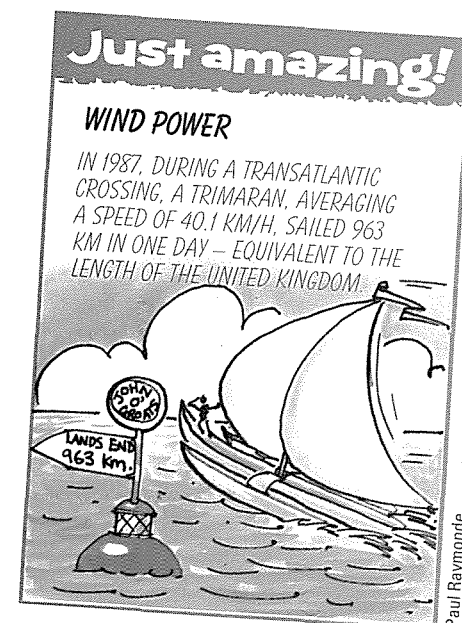
tage of a multi-hull is that it rides higher than a monohull, enabling it to skim over the water.

Boats with a single main hull attached to a small float are called proas. The world speed record for a sailing boat is held by *Crossbow II*, a 22-metre proa that averaged 66.8 km/h over a 500-metre course in Portland Harbour, Dorset, UK in 1980.

Wingsails

One of the latest high-performance yachts is a trimaran that uses a set of rigid, vertical wings instead of conventional sails. These so-called

Wing flap settings on the 32.5-metre-tall rigid mainsail of the *Stars and Stripes* are finely tuned. Wingsails – developed from aeroplane wings – are ideal for racing yachts because they work more efficiently the faster the yachts travel.



Paul Raymond

NEW CONCEPTS

Q DETONOGRAPHS

Q COMPUTER ART

STROKES

DEFERENT

ZIFA

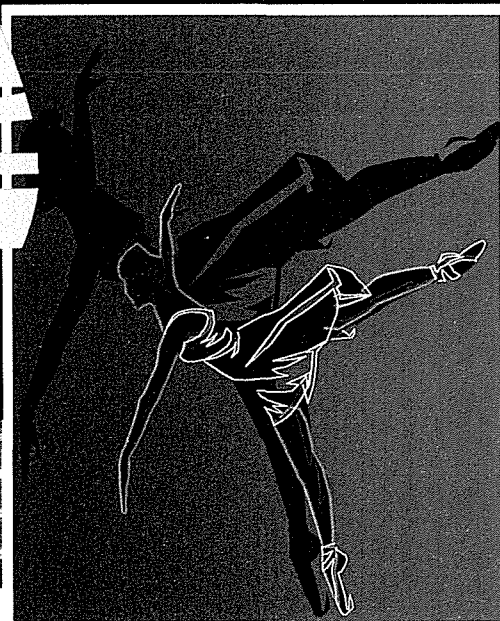
TODAY COMPUTERS, ROBOTS, and lasers are as much a part of the art scene as traditional canvas and paints. Techno-artists are even harnessing the power of modern plastic explosives to fuse and mould metal sculptures.

Artist Bryan Rogers is planning to release 64 tiny floating figures in the waters around Hawaii. They are solar powered and microprocessor controlled to generate patterns of electronic tones.

This is part of a project that he started in 1980 when he released 100 free-floating modules in the San Francisco Bay area. These, however, did not have the sound generating equipment built in.

Self-propelled

In the next phase of the project he plans to launch 16 modules that will be capable of both sending and receiving information. Then he plans to build a self-propelled, solar-powered unit capable of navigating itself completely around the world.



Using computers to produce sophisticated graphics is a major new art form. Pictures and colours never dreamt of before can be created and manipulated and, once on the computer, it is an easy step to animate a drawing (inset).

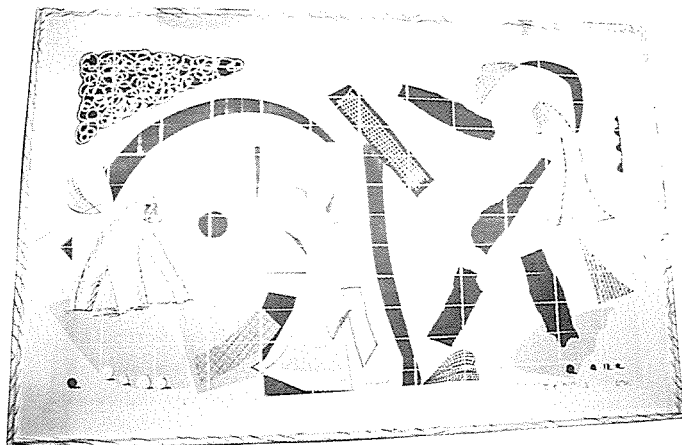


Rogers also makes sculptures from umbrellas that are periodically opened and closed by a pneumatic system and an electromechanical timer. He came to notoriety in 1977 with a sculpture that randomly stabbed a harpoon into an aquarium where a goldfish was swimming.

'Chatter, chatter'

Jim Jenkins specializes in making moving sculptures from TV sets. He used four to make a bucking bronco. Jonathan Borofsky made *20 Chattering Men* in 1984. Twenty life-size

Painting with sound is an innovation of artist **Alain Hüsson Dumoutier**. He wired up 400 lights behind a painted plexiglass screen. The lighting circuits are computer-controlled and voice-activated. Different tones switch on different coloured lights.



Daudier/Jerrican



David Hockney sent a drawing by fax from California, USA, to his native Bradford, UK.

she places thin coloured metallic foils, together with various objects such as cloth, string, or leaves, on top of the metal she aims to sculpt.

Plastic explosive

At a blast site in Socorro, New Mexico, a technician covers the whole design with a layer of C-1 Detasheet, a plastic explosive manufactured by the Du Pont company. C-1 Detasheet consists of pentaerythritol tetranitrate

aluminium figures were fitted with small speakers which muttered the words 'chatter, chatter, chatter'.

Some artists use their art to make a satirical attack on science. When a Los Angeles museum dropped and broke a unique 'lifting body' aircraft donated by NASA, Dave Quick produced *Mishap at the California Museum of Science and Industry*. In Quick's version, a rubber chicken falls on 'Tom Edison's first lightbulb' and 'the only intact dinosaur egg ever discovered'. And in *Little Nuke*, lights flash, dials spin, LEDs count furiously, alarms sound, a rubber chicken lays a model nuclear bomb and the sign 'Nuclear fission - evacuate' flashes.

Bomb art

Salvador Dali once exploded a bomb filled with nails against a copper plate, producing a striking but random pattern. Many other artists have used explosives in their work, but generally the results have been uncontrolled.

Now, however, Evelyn Rosenberg, a sculptor working at the New Mexico Institute of Mining and Technology, has harnessed the energy of high explosives to create preplanned bas-reliefs (shallow carvings set against a flat background) in brass, copper, and stainless steel.

Blast problems

Rosenberg's first attempts proved disappointing. Sometimes the explosives ripped holes in the metal or hurled materials through the air. After about 80 attempts, though, she was able to gauge the thickness of the metal and the strength of the blast so as to create attractive sculptures.

which she calls 'detonographs'.

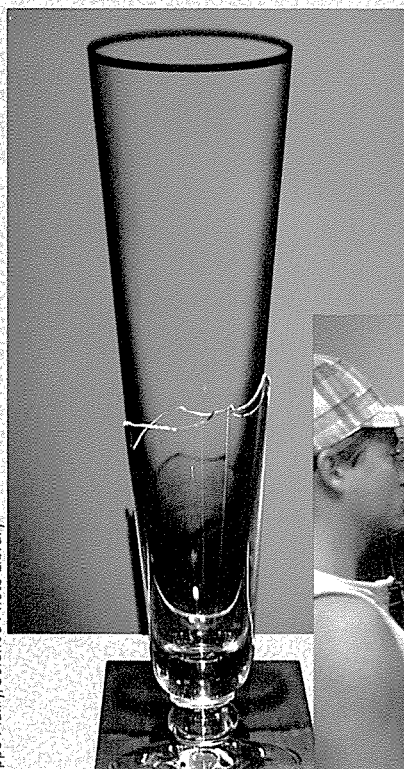
To produce a detonograph, Rosenberg first sculpts a bas-relief in plaster to form a mould. She covers the mould with a 100 x 130-cm panel of brass, copper, or stainless steel. Then

NEW DIMENSIONS FOR 3-D ART

A hologram of an object is made using two beams of laser light. One beam is bounced off the object on to a photographic film. The other beam travels

directly to the film where it interferes with the first beam (below). The resulting interference pattern, when viewed properly, creates a solid image of the original object.

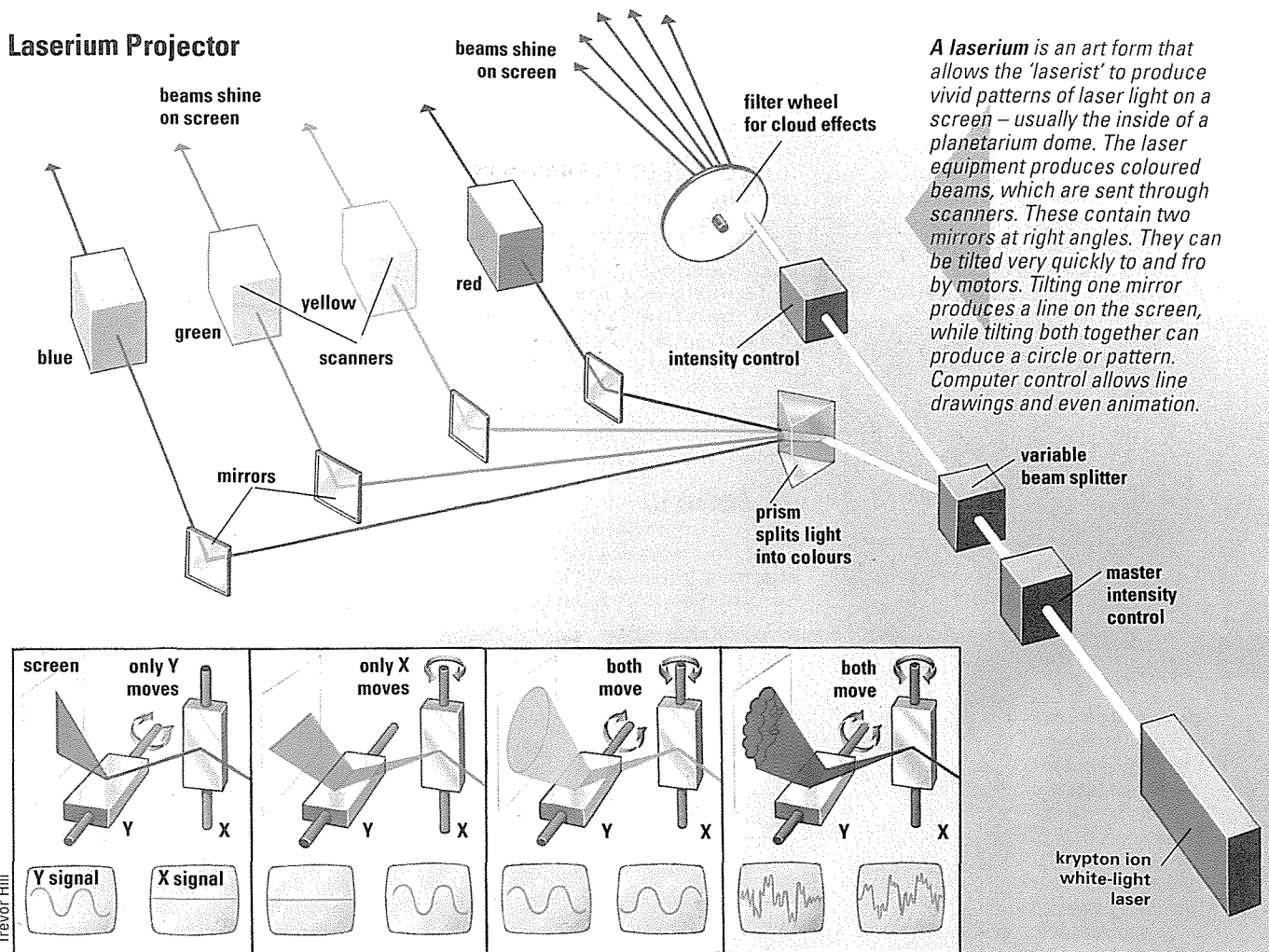
Many examples of holographic art already exist - like this holographic champagne glass, which is married to a real broken glass (left). In the future, however, this technique will be taken much further. It will be possible, for instance, to create fantastic scenes on a computer graphics screen and then generate a holographic image directly, using the information stored in the computer's memory.



Gamma/Frank Spooner Pictures

Philippe Plailly/Science Photo Library

Laserium Projector

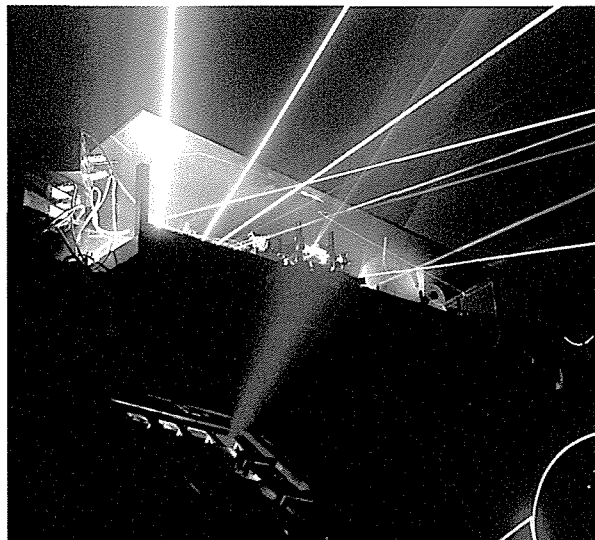


and cellulose nitrate with a plastic binder. It is constructed to detonate very fast to give an even blast.

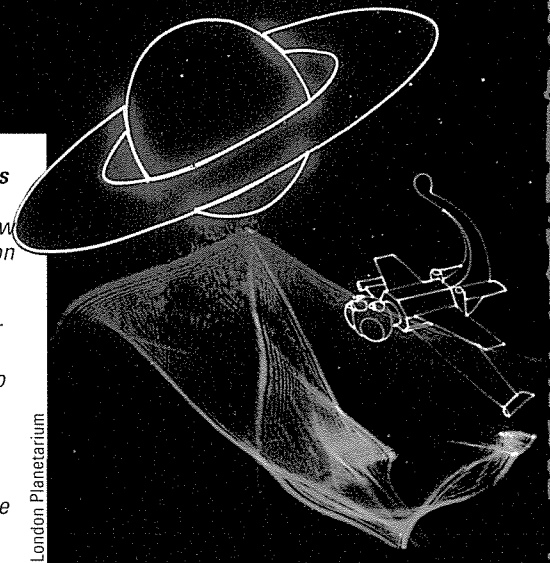
Fireball

As soon as the technician detonates this explosive sandwich, a 6-metre-wide fireball erupts from it. The explosion drives the metal panel into the mould in the instant before the mould shatters. At the same time, the tremendous pressure of the explosion clads the panel with the metal foils, adding regions of colour. The cloth, string and leaves are driven into the panel at a speed of 6,800 m/s and provide texture before disintegrating in the heat of the flames. Then Rosenberg cleans and polishes the panel to complete the artwork.

Other artists use a monitor screen

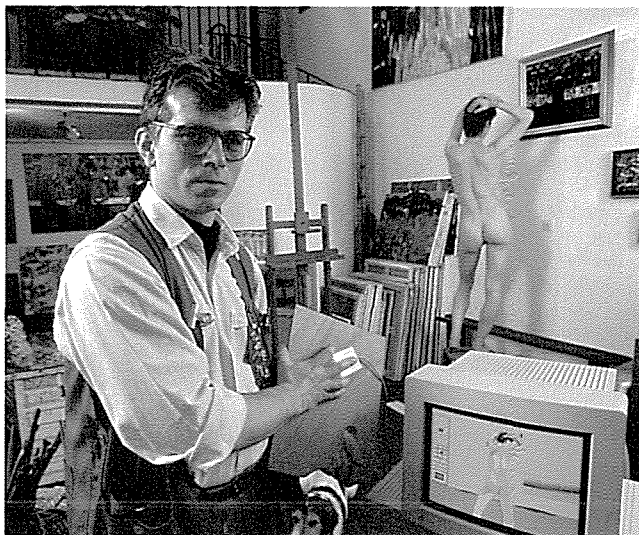


The beams of a laserium machine flicker across the screen rapidly as the scanning mirrors inside tilt under computer control. By scanning the same path repeatedly, a single beam turns into a line. The artist can 'draw' cartoons (below), which can be animated to music.



Traditional studies of the nude body can be given a new twist by painting on the computer rather than on a canvas. A number of devices have been developed to input the artist's work. Here a mouse is being used. The colours and shapes can be modified later.

London Planetarium



Gamma/Frank Spooner Pictures



in place of a canvas and a light-pen instead of a paintbrush. Along with a computer, these can be used to create fantastic, flowing images of things never even imagined before. Special software breaks the screen down into thousands of tiny picture elements, or pixels, and then controls the colour and brightness of each pixel according to the artist's wishes.

Modern computer graphics

tiny polygons, or flat, many-sided shapes, are then joined to this basic framework like a skin. The artist can select the precise hue of each facet from a palette of up to 16 million different colours offered by the computer. Other software enables precise control over the shading so that it is possible to create the illusion of solid surfaces and smooth curves. In the next stage, the artist adds texture to the various surfaces. The butterfly's wings can be made to seem transparent while the eyes can be given a mirror-like quality. Finally, the artist can call upon digitized data from actual scientific drawings to add a final touch of realism to the picture.

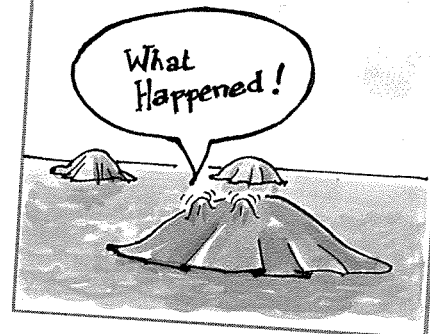
Zoom in

One of the great strengths of the computer is its ability to make rapid changes. If the artist, for instance, is not satisfied with a particular colour

Just amazing!

BIG IDEAS

IN 1983, CHRISTO CREATED THE WORLD'S LARGEST PIECE OF ART BY WRAPPING 11 ISLANDS OFF FLORIDA, USA, IN 603,000 SQUARE METRES OF PINK PLASTIC SHEETING.



Paul Raymonde

But art does not have to be confined to the screen. Imagine a house in which the walls can instantly change colour to match your curtains or your mood. This may soon be possible thanks to electrochromatic materials.

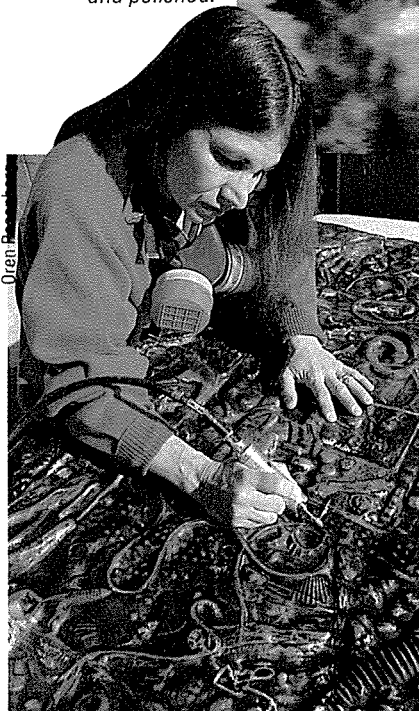
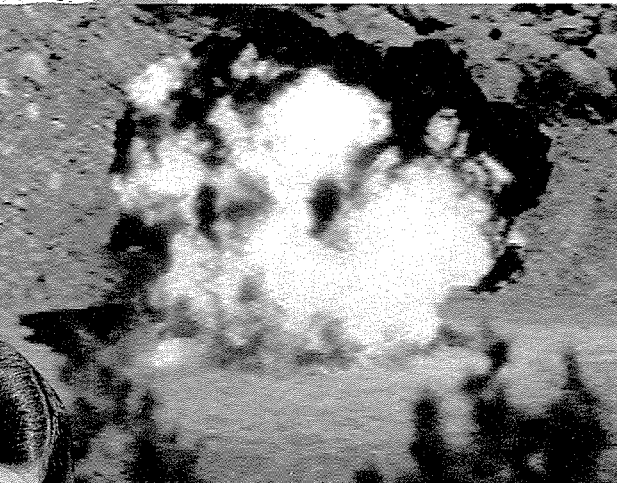
When an electric current passes through certain substances it alters their colour. This is because the electrons making up the current become attached to the molecules of the electrochromatic chemical, so altering the wavelength at which it gives off light. If the current is reversed, the electrons are driven out, causing the colour to change back again.

Moving paintings

Walls coated with electrochromatic material could be changed from red to green to blue by, for example, simply turning a knob that altered the current running through them. Patterns can also be created. In the same way, it may not be long before there are electrochromatic advertising posters in underground stations. In this new medium, artists could even create moving paintings.

Tootal Group

Detonograph artist Evelyn Rosenberg carefully prepares the mould (above). This is covered with a sheet of high explosive. The resulting bas-relief (below) is cleaned and polished.



programs handle everything from simple line-drawing to sophisticated shading, texturing and transparency effects. The artist uses a light-pen, electronic stylus, or mouse, to pick from a menu of commands or to sketch directly on to the screen.

A piece of computer art might begin with the construction of a simple 'wireframe' drawing of, for example, a butterfly. Thousands of

scheme or some aspect of the texture, then this can be altered in a matter of seconds. Other options allow the artist to zoom in on any part of the image or to rotate it in three dimensions. And, by creating a series of images, each slightly different from the one before, the computer can make realistic animations possible.

PUSH-BUTTON TEXTILE DESIGN

Textile designers are now using desktop computers to create the latest fashions. Designers can turn yarn into fabric and sketch a garment from the fabric without even leaving their computer workstations. As a result, a design process that previously took weeks or months can be completed in less than 24 hours. The images by colour monitors, or reproduced on colour printers, are so realistic that buyers from department stores are prepared to commit millions to a new range of clothes after simply seeing the screen displays or printouts. In the United States, AVL Looms of California, has gone one step further. When a design has been perfected on the computer, a second set of programs controls the loom that turns the design into a finished garment.





FAMILY PLANNING



URBAN MIGRATION



INFANT MORTALITY



Football stadium, USA. The US fertility rate is 1.8 children per woman. The population is still rising, however, due to the number of young adults born during the last 'baby boom'.

THE BIG SQUEEZE

Gamma/Frank Spooner Pictures

WHEN THE 20TH CENTURY started there were just two billion people on Earth. By the end of the century there will be more than six billion, and the population will go on climbing.

It is estimated that the population will reach its peak somewhere in the latter half of next century. How many people there will be on Earth then is not possible to predict accurately. It could be as few as 8 billion, it could be as many as 14 billion.

Family planning

The lower projection of eight billion assumes that in the next two decades the number of women using family planning in the developing world will increase to 71 per cent, which is the level in industrialized countries. Worldwide, the percentage of couples using contraceptives in the reproductive age range is 45 per cent. This figure is heavily influenced upward by the success of China's family planning programme. Excluding China the percentage worldwide is only 30 per cent.

The growth of population is not uniform across the world. The average population growth is 1.8 per cent, enough to double today's population in 39 years. But Italy's birth rate is just 1 per cent. Britain's is 1.4 per cent and the only country in Western Europe



Andrew McLennan/Science Photo Library

that is producing enough native-born children to replace its current population is Ireland.

Age concern

In the rest of Europe and North America, the availability of contraception has allowed people to choose to have less children. This declining birthrate itself causes an economic problem in these countries. More people are living well into retirement, but the number of active young people

Hong Kong ranks third in the list of the most densely populated countries and colonies in the world. Population is 5,761,000 in an area of only 1,037 sq kms.

who are working to support them is declining. In some countries it is predicted that with this 'greying' population the social services may soon run out of money to provide for pensions and medical care.

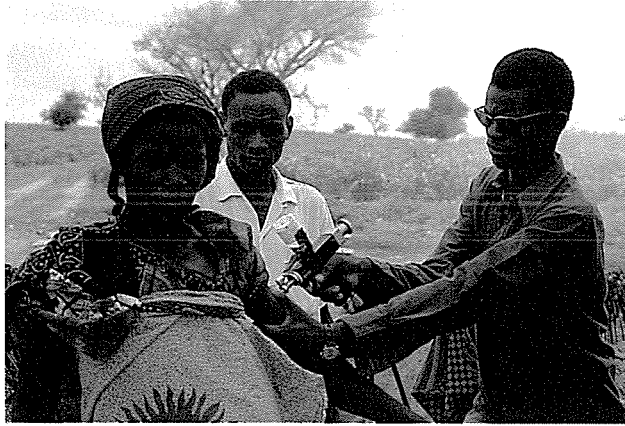
In developing countries the



population explosion is due in part to the cut in the mortality rate. These days medicine is much more widely available. Antibiotics and immunization have saved countless lives. DDT has killed many of the mosquitoes

52 million children were estimated to be employed in developing countries in 1980.

Hutchinson Library



Effective immunization depends on an efficient health infrastructure. Only 20 per cent of the world's children are protected against the six major killers: TB, measles, whooping cough, polio, tetanus and diphtheria. These account for five million children's deaths a year.

problems – poverty, hunger and high infant mortality. The social services, transportation facilities and agriculture all come under severe pressure.

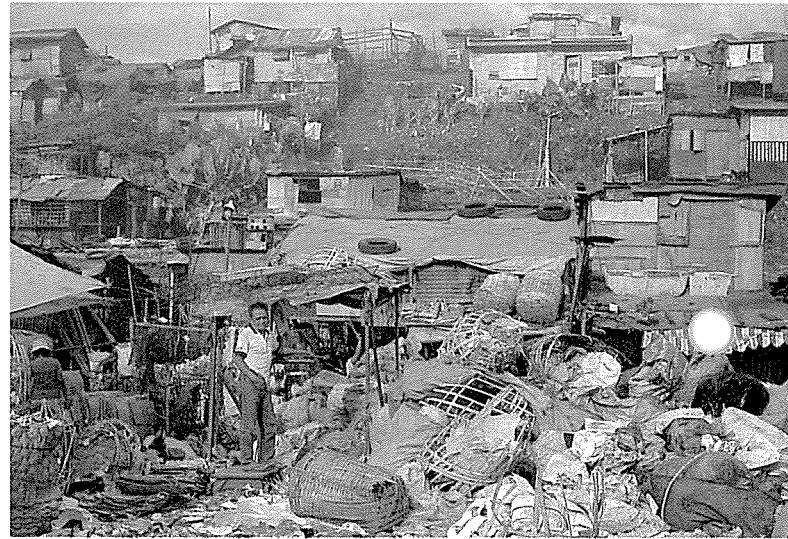
Many third-world countries have made enormous progress in increasing the percentage of children enrolled in schools. But population

growth means that the number of children not going to school has also increased. Resources simply cannot keep pace with need.

The same can be said of jobs, housing and hospitals. However quickly they are increased, they cannot keep pace with growing demand.

Shanty town, Manila, Philippines, where 60 per cent of households live below the poverty line and it is estimated that two-thirds of all new housing is illegal and uncontrolled.

By the year 2000 it is estimated that there will be 57 cities with over five million inhabitants (in 1950 there were only seven such mega-cities). 42 of these will be in the developing world.

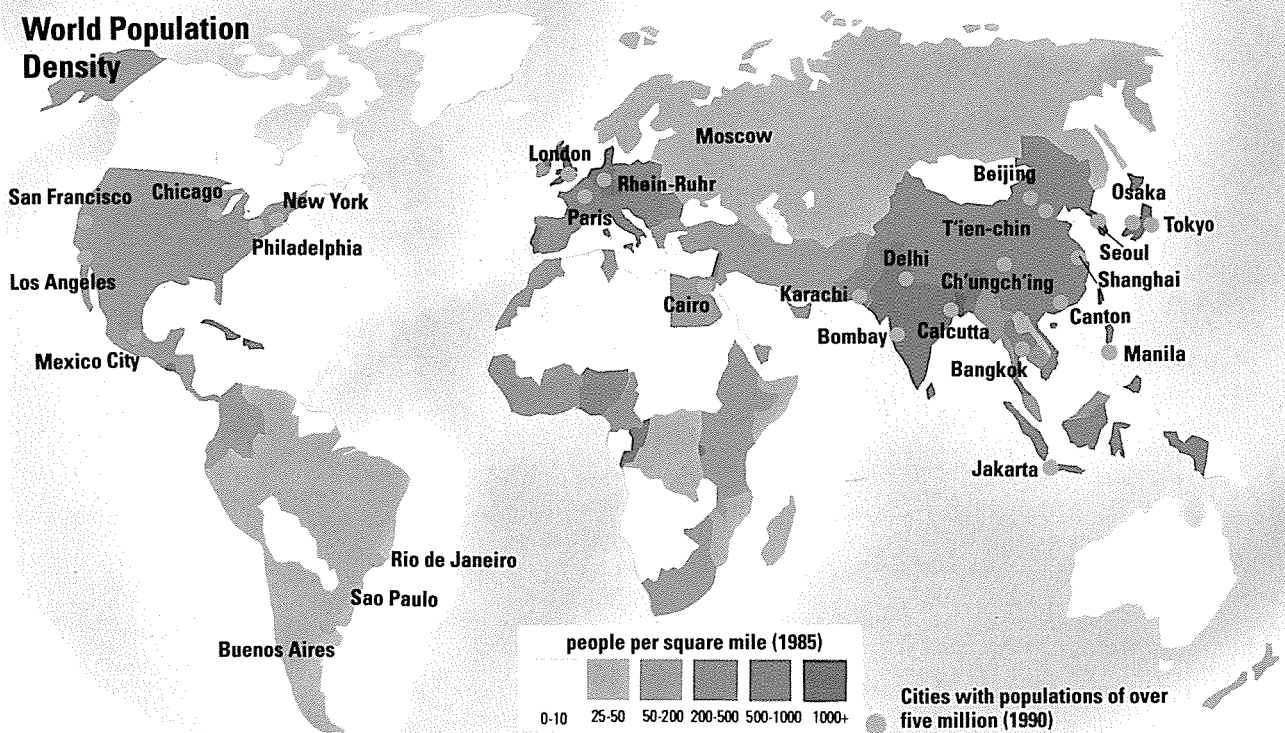


Rex Features Ltd

that carry malaria. Smallpox has been eradicated. Sanitation in many countries has improved, preventing diseases like cholera, and food aid has helped cut the death toll through droughts and other natural disasters.

Rapid population growth in developing countries brings with it many

World Population Density



Robert Harding Picture Library

John Hutchinson



These problems are compounded by the large numbers of people who migrate from rural areas to towns and cities as an escape from landlessness and rural poverty.

Rapid population growth also affects the natural

overuse of land. That leads to soil erosion and exhaustion. Productivity drops and with it comes famine. Although birth rates are going down it takes a long time for population to decline. For example, in the United States, the birth rate in 1989 was 15.9 per 1,000 and the death rate was 8.7 per 1,000. That gives a net increase of 7.2 persons for every 1,000.

40 million people die each year from malnutrition while nearly 40 per cent of the world's grain is fed to livestock for the North's meat-rich diet.

Rex Features Ltd



Rex Features Ltd

ZAPPING SPERM

A new contraceptive device that works by electrocuting sperm has already been tested on baboons. The device is around half a centimetre long and is anchored to the cervix by two plastic lugs. A 2.8 volt battery produces a tiny current in seminal fluid, immobilizing sperm in three or four minutes and preventing them passing through the cervix to fertilize the egg. Tests showed that 100 per cent of sperm could be stopped this way.

The battery lasts for ten years and so far no side-effects have been detected. But more tests will have to be carried out before this device is approved for human use.

before their parents are dead. This phenomenon is known as the 'momentum of growth'.

Family planning information and services have been the most effective methods of cutting population growth. In developing countries however, infrastructural development is often poor. Health and educational services are often centred around the capital and family planning information is not accessible to all those who desire it. It has been estimated that as many as one third of developing world couples who possess the motivation for family planning do not possess the contraceptive means. It has also been estimated that the birth rate in Africa, Asia and Latin America would drop by

environment. It puts pressure on land, water, forests and other natural resources. Population growth promotes rapid industrialization, bringing with it the problems of pollution. It also accelerates deforestation. There is a world shortage of fire wood for cooking and heating. And poor people are cutting down forests to provide farming land. When a growing population puts pressure on primitive farming methods, it leads to over-irrigation and the

PROFILE

CONTINENTAL POPULATIONS

	A	B	C	D	E	F	G	H
AFRICA	623	886	110	6.3	45/3	30	620	2.5
ASIA	2,995	3,611	82	3.6	35/5	36	1,020	20
NORTH AMERICA	272	296	10	1.8	21/12	74	17,170	30.5
LATIN AMERICA	429	537	57	3.7	38/5	68	1,720	3
EUROPE	497	506	13	1.8	21/13	75	8,170	24
USSR	286	311	25	2.5	26/9	65	7,400	19
OCEANIA	26	30	36	2.6	28/9	70	9,050	1.3

A population - mid 1988 (millions)

B projected population - 2000 (millions)

C infant mortality (deaths - 1,000 live births)

D total fertility rate (births per woman)

E % population <15 years/> 65 years

F % urban population

G income per head 1986 (\$ US)

H % of world energy consumption

This gap between births and deaths occurs in spite of a very low average family size.

Even at the replacement fertility levels - when each woman has an average of two children, in the long term 'replacing' her and the children's father - there will be more births than deaths. Those children are likely to be having children themselves

approximately one third if all the women who did not want any more children were able to stop giving birth.

Traditionally, in the developing world, children represent future security. They help with household and agricultural work and provide for their parents when they get older.

The status of women also has an effect on fertility levels. Many women,

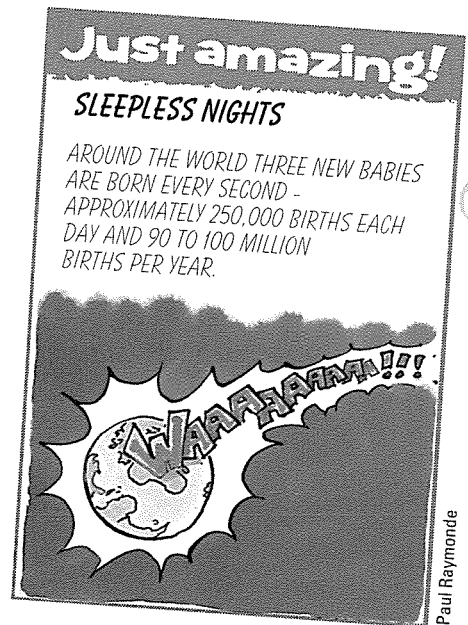
Slash and burn - destroying the rainforest in the Ecuadorian Andes to provide pasture for livestock. Increased population puts pressure on land resources.





World food supplies depend on more productive agriculture. The application of scientific knowledge produces high yielding seeds and improved plants.

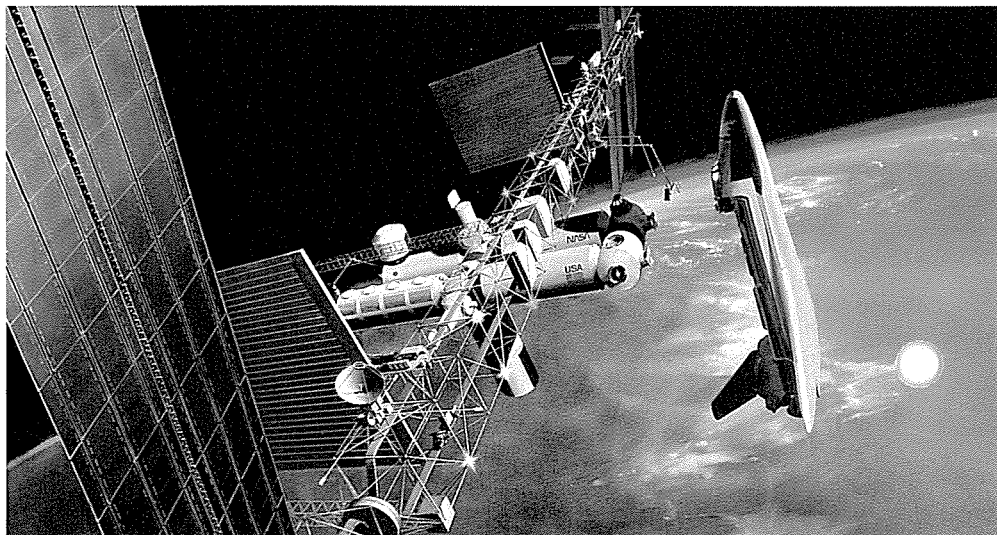
Homes in Space? This US Space station is under development and is due for permanent occupancy in orbit by the late-1990's. Scientific and technical research will be carried out in the gravity-free environment.



Ciba-Geigy Ltd especially in developing countries, have few options outside marriage and motherhood. Economic and social self-determination for women: education, health, equal access to land and rewarding employment plus control over their fertility help widen women's opportunities and reduce their dependence on children for status and support.

Education

Women with wage-paying jobs tend to have fewer children. Studies also show that women who have completed primary school have fewer children than those with no education. They delay getting married, learn



more easily about contraception and also suffer fewer infant deaths – high infant mortality is associated with high birth rate. Women's deaths as a result of childbearing are also much higher for those countries with a high birth rate. More women in India die as a result of pregnancy and childbirth in one day than in the developed countries in one month.

One child policy

In China, people have been encouraged to have only one child and, in 20 years, the birth rate has dropped from 3.4 per cent to 2.1 per cent. But recently, the Chinese government have realized that this policy is unrealistic and women over 30 are now allowed to have a second child if their first child is a girl. This means that China will overrun its end-of-the-century population target of 1.2 billion by some 50 to 80 million.

India started its family planning programme in 1952 and has reduced its birth rate to 2.1 per cent. This still means that India's population will double in just 32 years. Although the programme was in many ways a success, the decline in mortality and

the country's extreme poverty make further progress difficult.

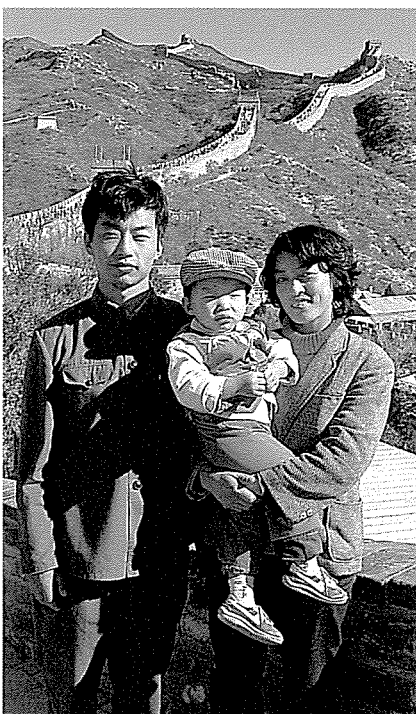
Since the population of India and China represent 37 per cent of the world's total, any upward revision of their fertility rates has a major impact on projected world population.

OVERCROWDING

Scientists have discovered that overpopulation has physical effects – in their own laboratories. Recent surveys of the well-being of animals kept in laboratories for experiments has revealed that keeping animals in overcrowded conditions creates all sorts of stress-related problems.

As well as behavioural difficulties, many rats were discovered to have high levels of hormones in their bodies, stimulated by stress, which made them useless when testing for toxins. In a comparison between isolated mice and overcrowded mice, the overcrowded mice were observably less healthy and were more vulnerable to gut parasites.

Macaques – a type of monkey often used in laboratories – showed a breakdown in the immune system.



China's one child per couple policy, in the world's most populated country, is an attempt to deal with an annual rate of increase of 12.8 million people.





Q ETHANOL

Q GASOHOL

Q HYDROGEN

Energy and pace are essential elements of Formula One racing, especially at the Indianapolis 500 but the cars use methanol rather than pump petrol.

NEW FUELS

CARS THAT RUN ON PETROL may soon be a thing of the past. In an effort to cut drastically the amount of pollution caused by cars, manufacturers are turning to alternative fuels that burn efficiently but cleanly.

At present, cars, trucks, buses and other road vehicles emit huge quantities of dangerous gases. Some of these, such as carbon monoxide and ozone, are a direct health threat to people living in large cities, where car fumes tend to be most concentrated.

Other waste gases, such as carbon dioxide, contribute to global warming through the greenhouse effect, while still others, including the oxides of sulphur and nitrogen, result in acid rain.

The lead added to petrol to improve combustion causes brain damage.

To protect the environment, increasingly strong laws are being passed in Europe and North America that will force manufacturers to produce cars with cleaner exhausts. They have sent the car-makers hurrying to their computers and laboratories in a race to develop effective new fuels, together with new engines that can use them.

Q Grain alcohol

Alcohol may not seem the likeliest substance to replace petrol, but in Brazil hundreds of thousands of cars are already running on ethanol – the type of alcohol found in beer and

wine. Ethanol, or grain alcohol, is obtained by fermenting crops such as sugar cane, corn and sorghum which are grown for this purpose all across Brazil.

Like the chemicals in ordinary petrol, ethanol is a hydrocarbon. In other words, its molecules contain carbon and hydrogen atoms linked together. But there are fewer of these atomic links in ethanol than in petrol, so, when ethanol burns, it breaks down more easily and gives off smaller quantities of pollutants. Ethanol's main disadvantage is its fairly high cost. A better and cheaper alternative, some experts say, is methanol, or wood alcohol.

Q Indianapolis 500

Methanol – the kind of alcohol found in methylated spirit – gives off only about one-tenth the amount of toxic pollutants that petrol does when it burns. It also delivers more power, which explains why all cars taking part in the Indianapolis 500 now have methanol-adapted engines.

Running on pure alcohol is difficult for a car that has been designed to use petrol. But in some countries, such

Robert Brown/Allsport



A methanol-powered car needs a smaller engine, smaller fuel tanks, smaller exhaust system and smaller cooling system than a petrol-driven car. This means the car, especially the front end, can be trimmer and more aerodynamic. The double-clutch start-stop system shuts off the engine whenever the car slows, saving even more energy.

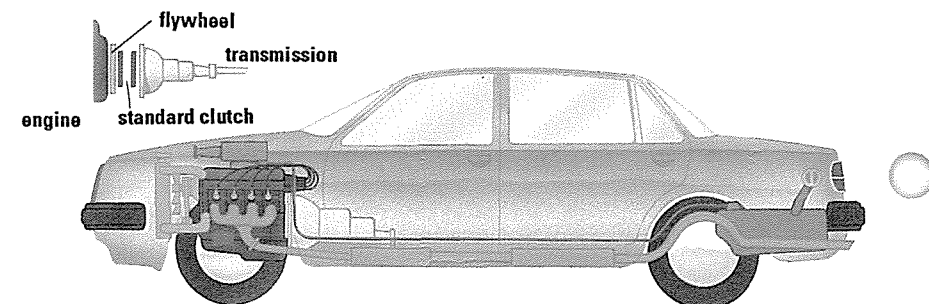
WIND-POWERED CARS

The ultimate in pollution-free motoring may be to tap the energy of the Sun or the wind. Experimental vehicles fitted with solar cells have already been tested and have even competed in a race across Australia. But how could a car make use of the wind? One possibility would be to fit a car with rigid sails controlled by microcomputer. Sensors would tell the computer which way the wind was blowing from one second to the next so that the computer could adjust the sails accordingly. Alternatively, the car could be equipped with a wind-turbine that produces enough electricity to maintain cruising speed.

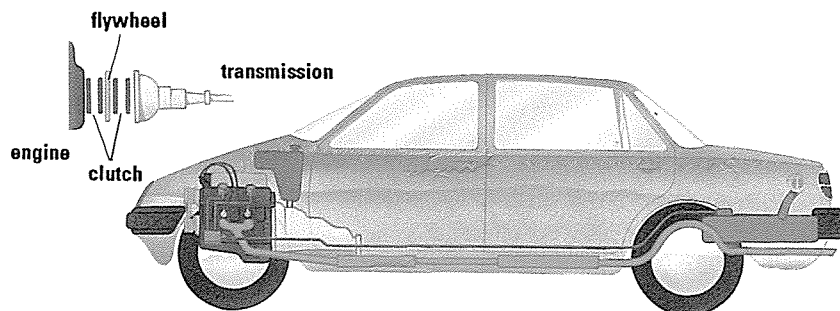
as the US, gasohol – a mixture of 10 per cent alcohol and 90 per cent petroleum – is gaining in popularity. The next step may be to manufacture vehicles that can run efficiently on so-called M85, containing 85 per cent methanol. Finally, when the demand is high enough, manufacturers may produce M100, or 100 per cent methanol-burning cars. An engine built specifically to use methanol could be smaller, lighter and more powerful than a petrol-driven one.

Waste gas

With crude oil supplies expected to run low over the next 50 years, it will be important to develop fuels that come from sources other than oil. Methanol, for instance, could be manufactured from natural gas that is



Petrol-Driven Car



Methanol-Driven Car

Trevor Hill

currently vented or burned off at remote oil wells. Alternatively, it could be made from coal, which there are still plentiful supplies of in many locations around the world.

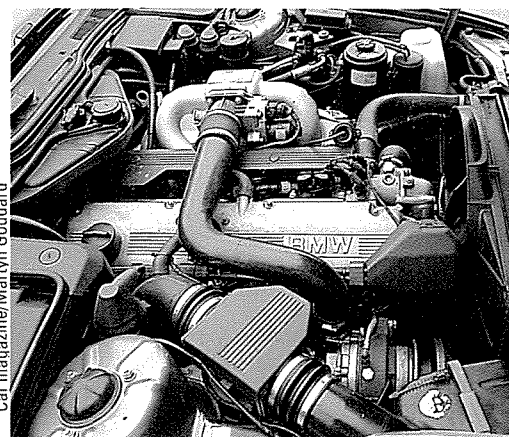
Natural gas itself has been proposed as a car fuel of the future. But it has to be squeezed under a pressure of about 700 to 1,000 kg/cm² in the cylinder for it to be useful. This would demand very heavy tanks, which would limit a vehicle's performance and fuel efficiency.

Hydrogen-powered engines are

another possibility. However, at the moment, hydrogen is difficult to produce in large amounts and hazardous to store and distribute.

Variable fuels

For now, the best solution seems to lie with 'variable fuel' vehicles: cars that can run on petrol, ethanol, methanol or any combination of the three. Such cars have an optical sensor in the fuel tank, which is connected to a control module that makes the necessary adjustments to the engine.

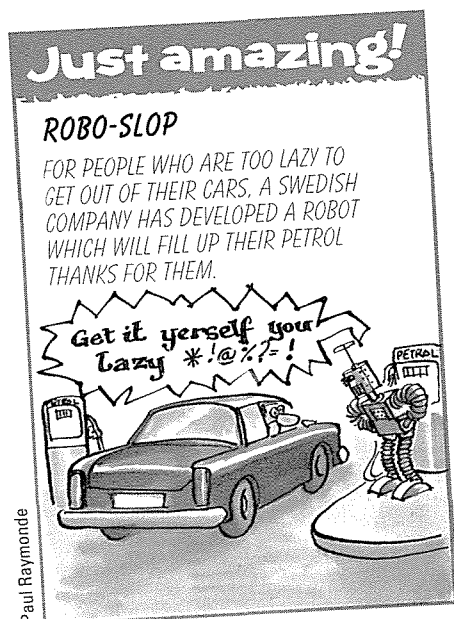


Car magazine/Martyn Goddard

Car engines can be modified to take hydrogen fuel. It is efficient, produced easily from water and non-polluting, but there are problems. Hydrogen has to be stored as a liquid at low temperatures, is very volatile and potentially explosive. The slightest spill could be dangerous. Prototypes (below) have to have much larger fuel tanks too. But hydrogen is probably the fuel of the future if ways can be found to store and distribute it safely.



INS/Jerrican



SAVE IT!



Stockholm Energi **AT THE PRESENT RATE,** the world reserves of coal will start to run out in about the year 2220, natural gas in 2050 and oil in 2020. Even supplies of nuclear fuel are not unlimited.

Most electricity is generated by turbines driven by steam that is produced by coal, oil or nuclear fuel. But the problem is that at least 10 per cent of the heat used to make steam is wasted, while only 30 per cent of a station's steam energy is converted into electricity.



Waste heat

A combined heat and power (CHP) plant can exploit this normally wasted energy, by operating in an unusual way. A CHP plant generates less elec-

Combined heat and power plants are used successfully in Scandinavia.

They produce electricity and warm water, which is pumped through pipes (right) to nearby houses.



Stockholm Energi

tricity than a conventional power station, but the waste water is at a much higher temperature. This is then pumped along large pipes underground to blocks of flats and factories nearby. Here it is used for room and workspace heating and as an inexhaustible hot water supply.



Overall, CHP plants raise the efficiency of energy production to 70 or 80 per cent – compared to some 30 per cent efficiency at an ordinary power station. Even with the added expense of the pipes and pumps needed to carry the hot water, such schemes have proved attractive.

Producing steam at a much higher

THE GAS GUZZLER



Oil shortages and soaring prices at the petrol pumps in the early 1970s led to a major rethink of car design – especially in the United States where huge, gas-guzzling cars were once all the rage. Quickly, car manufacturers began to look at ways to improve fuel economy. This involved drastically reducing body weight, making the shape of the car more aerodynamic, and cutting engine size while boosting performance. Most recently, computers have taken on a major role in the car industry. Huge, supercomputers are used to model every aspect of a new automobile design from simulated wind-tunnel tests to detailed engine analysis. At the same time, microcomputers are being used increasingly to monitor and control the engine to achieve maximum efficiency.

The National Motor Museum, Beaulieu

This small tower of solar panels provides enough electricity for one family living on a remote island in Sweden. The electricity made during the day is saved in batteries for use at night.

temperature is the easiest way to boost the heat efficiency of many types of power station. For example, the steam supplied to the turbines of a conventional coal-fired station has a temperature of about 540° C. If this could be raised to 1,200° C, the efficiency with which heat energy is converted to electricity could theoretically be much greater. New materials that could withstand such temperatures will be needed for the turbines, heat-transfer units and piping.

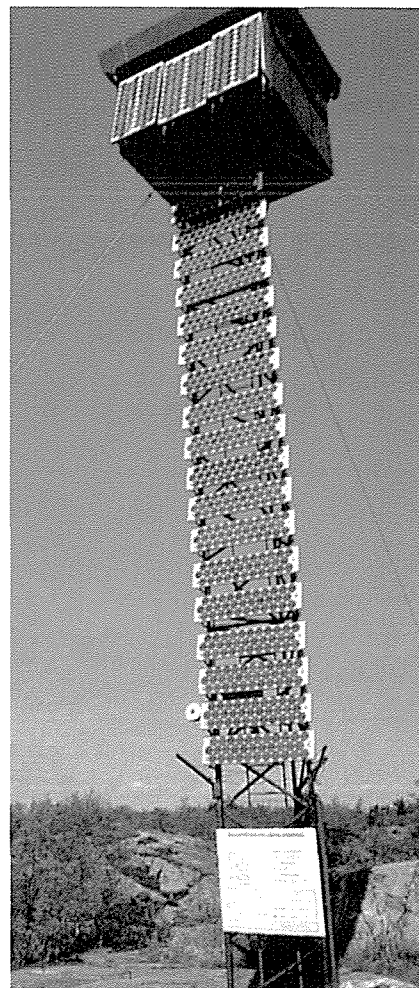
Progress in materials technology now makes this a real possibility for the near future. Ceramics such

as silicon nitride and silicon carbide are stable for long periods at temperatures exceeding 1,200° C. They may soon be used to make heat-resistant turbine blades. Advanced metals are another possibility. The high operating temperature and heat efficiency of nickel aluminide – a so-called inter-metallic alloy – might make it very useful for future turbine parts or super-hot, pressurized steam piping.

Fuel cells

Fuel cells provide the best opportunity for overall efficiency. Phosphoric acid fuel cells rival CHP plants in efficiency, and experimental models in Japan and the US can achieve almost 90 per cent efficiency overall. They work by direct chemical reaction between hydrogen or methane and oxygen, so no polluting nitrogen oxides and less carbon dioxide are produced.

Producing en-



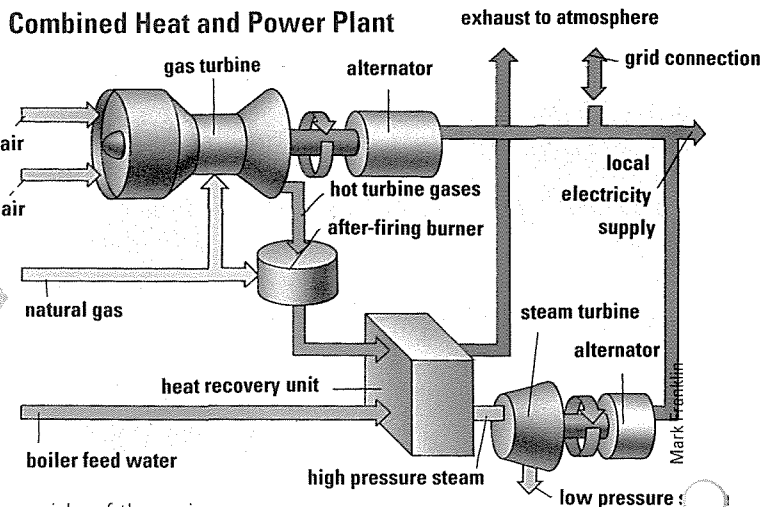
Alf Linderheim/Vattenfall

minimize the amount of heat being lost in winter. They also prevent excessive outside heat in summer from getting in. Careful positioning of large windows on the south side of buildings allows solar energy to be captured for space heating, while active solar panels supply energy for heating and making hot-water.

In the more distant future, 'smart' materials will alter their properties as

Combined Heat and Power Plant

A combined cycle CHP plant uses both a gas turbine and its exhaust heat powering a steam turbine to generate electricity. Heat in the exhaust steam from the steam turbine is not wasted either. It can be used for central heating in local buildings.



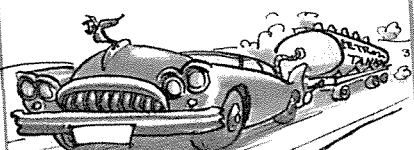
ergy efficiently is one side of the coin, using it efficiently is the other. New homes and factories are increasingly being designed with energy conservation in mind. Better insulation, double-glazing and other improvements in building materials help

external conditions change. A smart insulator coating the roof and outside walls could respond to cooler weather by letting less heat escape. In warmer weather, it would let the right amount of heat enter.

Just amazing!

GAS GUZZLERS

THE AVERAGE AMERICAN GETS THROUGH 4,500 LITRES - THAT'S 25 BARRELS - OF OIL A YEAR. IF OTHER NATIONS USED AS MUCH AS AMERICA, THE WORLD'S OIL RESERVES WOULD BE USED UP IN EIGHT YEARS.



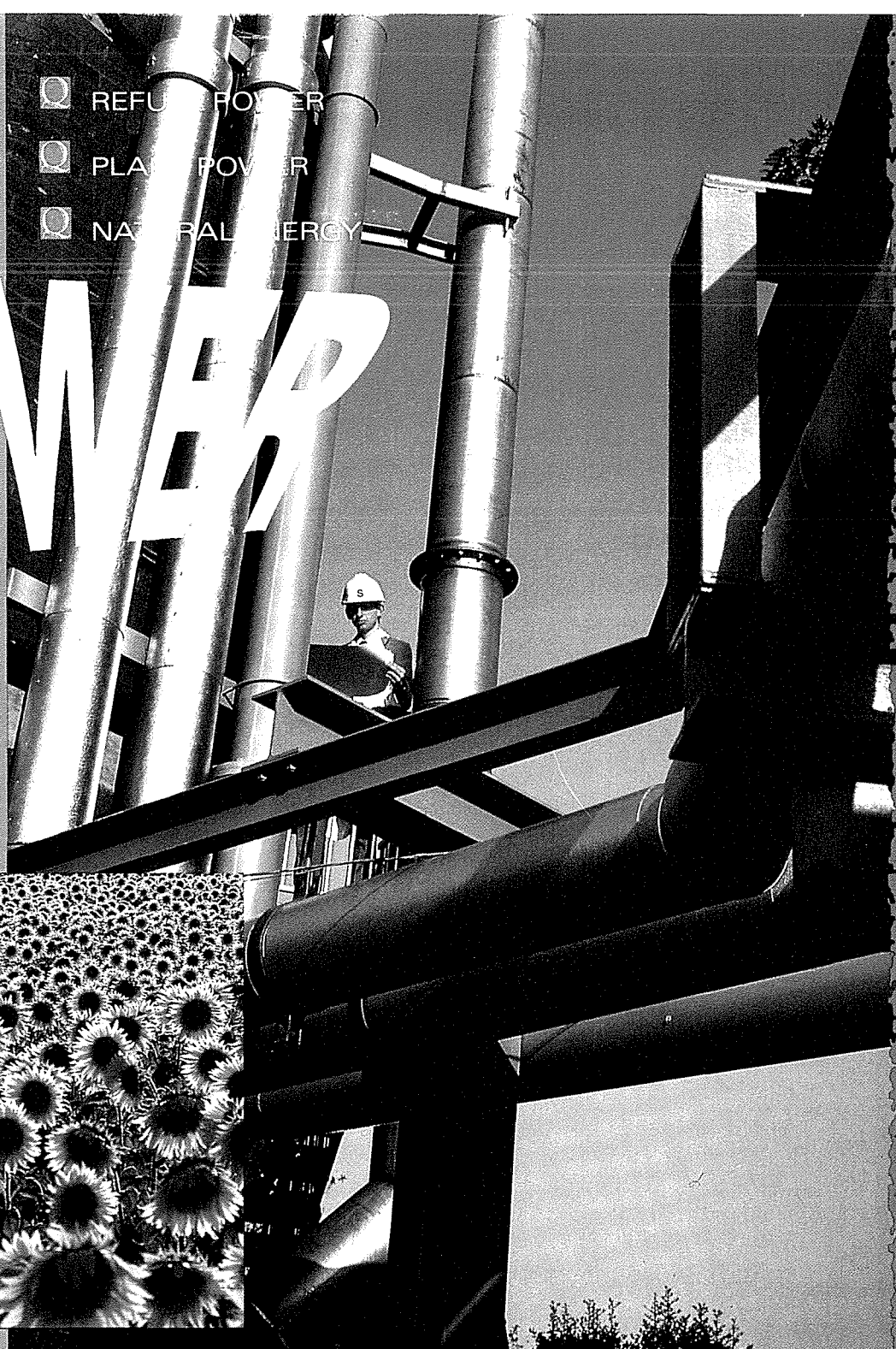
Paul Raymond



TRASH POWER

- REFUSE POWER
- PLANT POWER
- NATURAL ENERGY

An inspector checks the steam-carrying pipework at a hospital incinerator (right). Waste heat from the incinerator is recycled to provide extra power. Sunflowers (below) may seem an unlikely source of energy, but their oil can be used as fuel.



Shirley Rex/Features

EVERY YEAR, 250 MILLION tonnes of trash are tossed out by households and companies in America alone. Yet most of that solid waste is still useful. About 11 per cent of it – mostly glass, aluminium, newspaper and plastic – is recycled. The rest is a potentially valuable source of energy.

Energy can be extracted from rubbish in several ways. In some waste power plants, the refuse is simply fed directly into large incinerators and burned. Others pre-treat it to ensure that it burns evenly and efficiently, although this adds to the running costs. The heat is used to make steam to drive a turbine and

produce electricity as in a conventional power station.

Careful control of the temperature, burning time and flow of materials in the incinerator is important. In this way, a waste-to-energy plant can generate an average of 500 kilowatt-hours of electricity for every tonne of garbage.

Future prospects

A city the size of Frankfurt, for example, with 650,000 inhabitants, creates more than 150,000 tonnes of rubbish a year. Burning this could provide the city with about a tenth of its heating needs. Similarly, in the USA, waste-to-energy plants may handle as much as 17 per cent of the nation's

solid waste by the year 2000.

A different approach is to turn refuse into more convenient forms of fuel. Through pyrolysis, for instance, waste organic matter (household rubbish, wood and agricultural waste like straw) is burned at high temperatures in the absence of oxygen to produce low-grade gas and oil fuels. Alternatively, a process known as liquefaction converts rubbish into liquid fuel by heating it in a solvent with carbon monoxide and a catalyst.

Solid fuel, called refuse-derived fuel (RDF), can also be obtained from waste. The organic portion of the rubbish is separated, shredded, dried and compacted into pellets, briquettes, or logs. These can then be

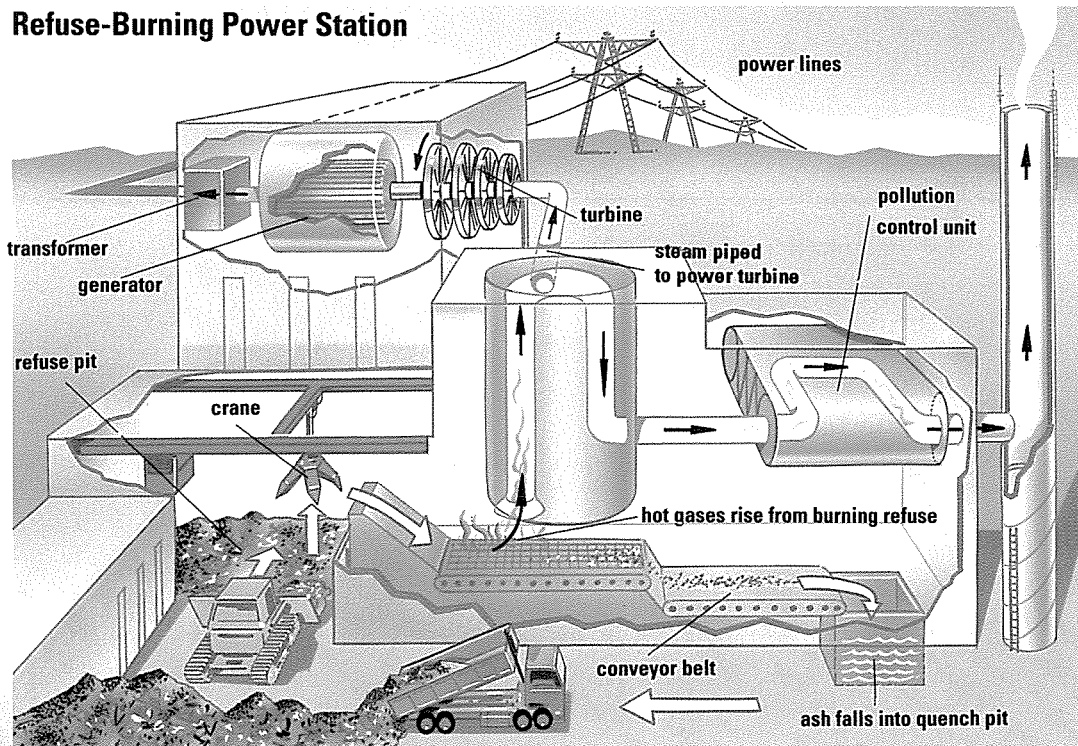
James Stevenson/Science Photo Library



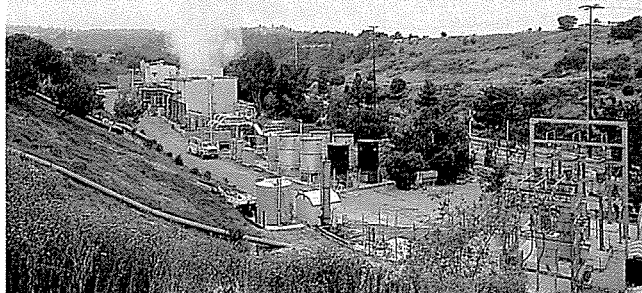
In a refuse-burning power station, refuse is delivered by lorry and then passed along a conveyor belt to be burnt. The hot gases rising from the burning rubbish heat the water in a boiler, and the steam drives a turbine generator.

This gas recovery plant in California, USA, uses methane gas released from a waste dump to produce electricity. The gas is collected and then used to produce steam to power a generator.

Refuse-Burning Power Station



Hank Morgan/SPL



burned in solid fuel furnaces to provide about 60 per cent as much heat as an equivalent mass of coal.

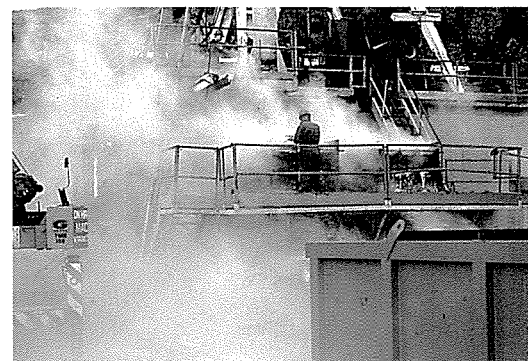
Buried in rubbish tips and landfills, plant and animal remains rot slowly in an oxygen-free, or anaerobic, environment. First, the complex organic compounds in paper, animal and vegetable matter break down into

sugars and fatty acids. Then these substances decompose to give biogas – a mixture of 40 per cent carbon dioxide and 60 per cent methane.

Normally, the biogas works its way to the surface and escapes

ready extracted from sunflowers and used to run tractors and other farm machinery. Current plant-derived fuels are not as efficient as petrol or diesel and give off more carbon. However, new plants may be developed in future to overcome these problems.

GEOTHERMAL POWER



In certain parts of the world, natural, hot, underground water is already being used as a source of energy. Ten per cent of New Zealand's electricity needs, for example, are supplied by this geothermal power.

Exploiting the Earth's natural energy supply is straightforward when it simply involves bringing water to the surface. But in the future, scientists hope to be able to tap the geothermal power stored in dry rocks, even if they lie several kilometres down.

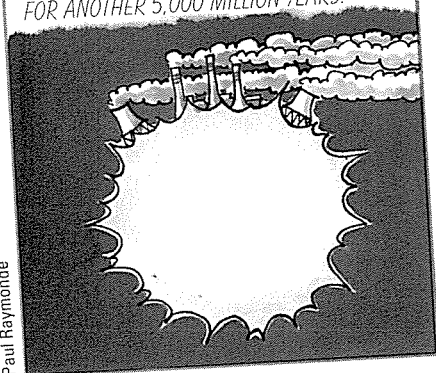
This could be done by pumping cold water down a well into cracks in the hot rocks. Then, after the rocks had heated the water, it would travel to the surface through a second well and could be used to drive turbines to produce electricity in the conventional way.

Can e School of Mines, Geo Thermal Energy Project

Just amazing!

HOT STUFF

EVERY SECOND THE SUN GENERATES 4 MILLION TONNES OF ENERGY AND WILL CONTINUE TO DO SO, IT IS THOUGHT, FOR ANOTHER 5,000 MILLION YEARS.



Paul Raymond

into the atmosphere, where it contributes to the global greenhouse effect. However, it can be carried away in pipes and used directly in boilers or kilns or in electrical generation. Over a period of 10 to 15 years, the potential output from one tonne of landfill waste is about 400 cubic metres. When burned, the biogas releases two thirds as much energy as natural gas.

In China, over 7 million family biogas units have already been installed. These use human waste, animal manure and other agricultural waste as their basic fuel and produce gas for cooking. As the dung rots down, the action of bacteria produces biogas. Now, scientists are searching for new types of micro-organisms to improve biogas output. Biogas digestors may eventually produce enough heat and power to supply

Plant power

Plants may be used in two different ways to provide energy in the next century. First, specially developed, fast-growing trees and shrubs may be burned to provide energy directly. Second, selected plants may yield fuels such as diesel substitute, which can be used as alternatives to petrol.

In Zimbabwe, for example, oil is al-



TRAFFIC

IN THE 20TH CENTURY, WHEN people want to move from one place to another, they get in their car. In the 21st Century, that may not be possible.

Already the traffic in cities is grinding to a halt. In most major cities, there are huge traffic jams during the 'rush hours' when people are going to and from work. But planners have found that building big new roads is not the answer. In fact, bigger roads make the traffic slower.

Drivers are attracted by new, wider roads. Traffic volumes increase until

congestion forces the speeds down to the levels of the old narrow roads.

Los Angeles, for example, was the first city in the world to be built with the motor car in mind. It is well served with huge motorways that criss-cross the city. Even the streets in the city centre are broad and spacious.

Surveys show that in Los Angeles, there is only 1.1 person per car per journey. There could not be less than one person per car – every car needs a driver – so 1.1 person per car per journey means that in only one in every ten journeys is there a passenger. There are only ten countries in the world that have more cars than Greater Los Angeles. This is why the city is jamming solid.

Years of widening the freeways have not done any good. A recent

plan to double-deck them was abandoned when planners estimated that the new double-deck freeways would reach their capacity within 15 years. This, of course, would be totally uneconomic. The best they can hope for is 'balance congestion' – enough congestion on the roads to deter other motorists from making it worse.

Most planners now see that the only solution is improved public transport. However, in most cities it is impractical to build new underground or overground railway systems. Digging tunnels for underground railways, for example, is prohibitively expensive and most modern systems are almost as congested under the ground as they are above it.

Going overground

Building new overground railway systems is even more difficult. Expensive buildings have to be bought by the transportation authorities and demolished, usually against the wishes of residents.

Using the existing roads more efficiently seems to be the only solution. That means encouraging people to use buses and tram systems. By carrying large numbers of people in a single vehicle, congestion is reduced. However, buses are slow and inefficient because they are caught up in current traffic jams. And tram systems cannot be built easily in streets that are already jammed.

Many city authorities are trying to discourage people from using their cars. In Tokyo, drivers must prove that they are using off-street parking before being allowed into the city. In Osaka, cars must give way to pedes-

Over 80 cameras monitor traffic along France's A-40 – a new motorway linking Lyon and Geneva that cost over 2 billion francs and took 10 years to build.



P. Seaward/Tony Stone Photo Library, London

P. Psaila/Gamma/Frank Spooner Pictures



GRIDLOCKING

Many cities are built on a system of streets that run at right angles to each other in grid formation. This means that if one street is blocked, it quickly blocks all the streets that run across it. This in turn blocks all the streets that run paral-



Ed Rooney/Tony Stone Photo Library, London

lel to it. Even in a small area, if the four sides of one square block is solidly congested, traffic becomes 'gridlocked'.

Computerized central traffic control systems, however, can help to ease gridlocking. Such systems are based on remote video monitors, which operate traffic lights according to the congestion at various points.

General Logistics PLC

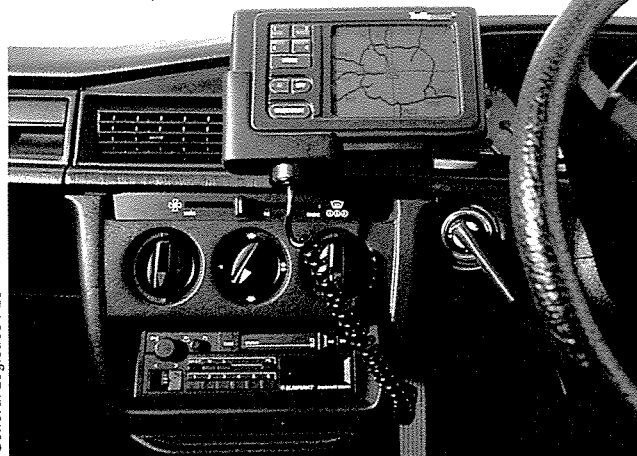
trians. In Stockholm, it is planned to issue a toll card which reduces in value every time the owner drives his car into the city. The card also doubles as a season ticket, giving free travel on public transport. Paris is trying to discourage drivers by cutting 200,000 parking spaces. Bordeaux plans to ban cars from 25 per cent of its streets by the year 2,000.



Divided city

Groningen in the Netherlands has cut inner city congestion by 23 per cent by dividing the city into four cells. To get from one cell to another, the driver must return to the city's ring road and drive back in again. In Freiburg, Germany, an ultra-cheap season ticket scheme for public transport has cut the use of cars by 18 per cent.

Singapore has a system that forces drivers to buy an extra licence to enter the city centre. In just seven years this scheme has saved an estimated £420 million in road building and has prevented an estimated doubling of car ownership.



Trafficmaster

provides the motorist with information on the speed, direction and length of motorway tailbacks. Infrared sensors mounted on motorway bridges compute the average speed of the traffic below and relay the information to the dashboard receiver unit if the speed drops below a pre-set threshold of 40 km/h.

Just amazing!

CAR CHAOS

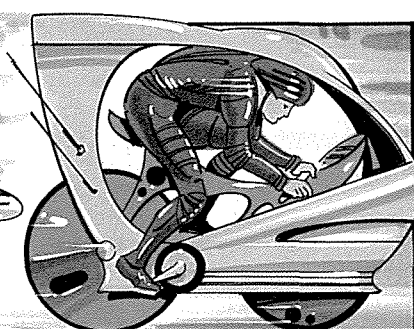
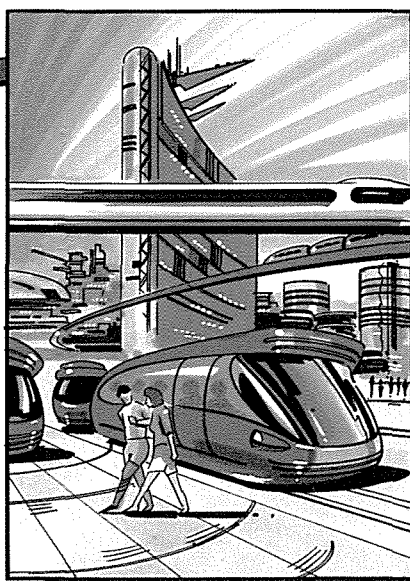
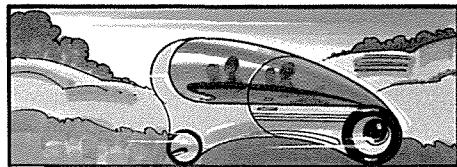
AT THE EAST LOS ANGELES INTERCHANGE, A SIX-ROAD JUNCTION, THE AVERAGE WEEKDAY VOLUME OF TRAFFIC IS OVER HALF A MILLION VEHICLES - 60 CARS A SECOND.



Paul Raymond

INTO THE FUTURE

AN END TO CONGESTION



▲ Private cars will be discouraged in the 21st century. They will be banned from the city centres and only allowed in the countryside on long trips.

▲ Cities will pride themselves on their public transport, which will use computers to integrate underground and overground train, bus and tram systems.

▲ Citizens will only be allowed to walk in the city centre. Long journeys within the city will be by bicycle. However, bicycle congestion may become a problem.

Joe Lawrence





VISION SUBSTITUTES



DIRECT IMPLANT



READING MACHINES

VISION

Macular degeneration – the weakening of nerve cells on the retina due to the process of ageing – is one of the most common causes of blindness.

Alexander Tsirlas/Science Photo Library

ALL FORMS OF BLINDNESS may be curable in the 21st century. Already work is underway that will input pictures from minute TV cameras directly into the brain.

The signal from the camera can be fed into the brain in two ways. A hole can be cut in the skull and the output from the camera fed into the brain after it has been processed by a small computer. Alternatively, a small radio receiver could be implanted in the brain, which would be fed by a transmitter lodged outside.

Image processing

Although it is already possible to stimulate the vision centres, not enough is known about the working of the brain to produce images of the shapes and colours sighted people see. What is holding up this research is not the technical difficulties of image processing, but knowledge of the workings of the brain itself.

A more promising line of research in the short term is vision substitution. Here, the signal from a camera is pro-



Operation Raleigh Picture Library

cessed and conveyed to the user by touch or sound. Pads are fixed to the stomach or back that stimulate the skin electrically or by tiny pin pricks. This way patterns and textures can be mapped out. Otherwise, the visual signal can be processed into an audio signal and fed into the ear.

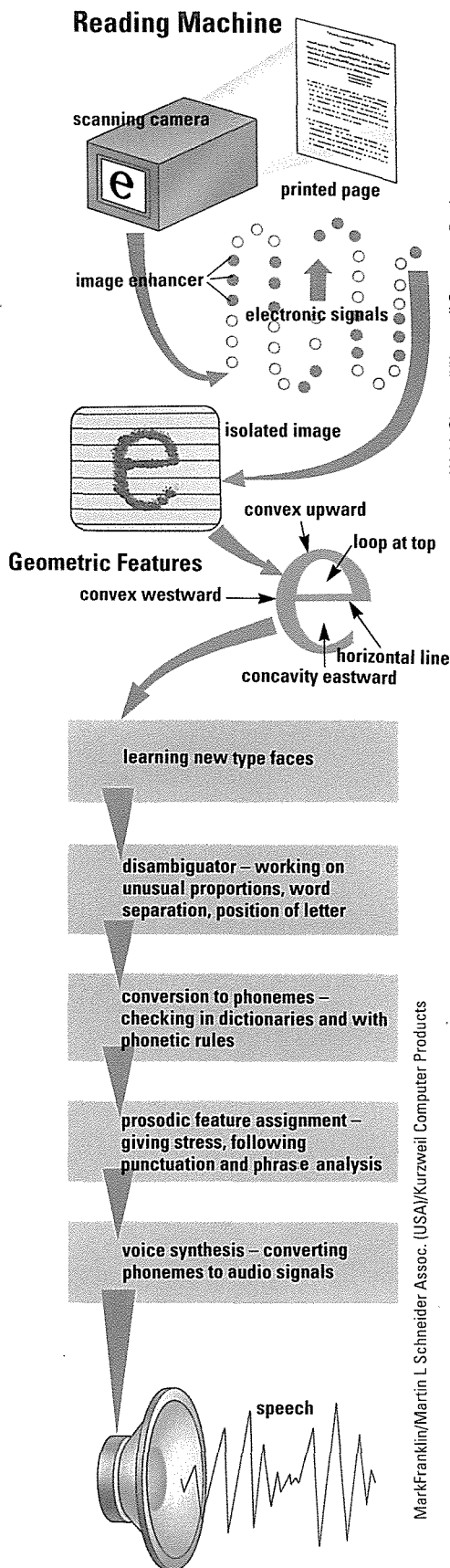
The problem with vision substitution is that the vast amounts of information contained in a picture

Magnifiers may be worn by patients after surgery until full sight is restored.

cannot be conveyed through any other channel. However, pictures can be simplified to straight line drawings, say, so the blind person can get some idea of what is happening around him or her. Work done by the military in



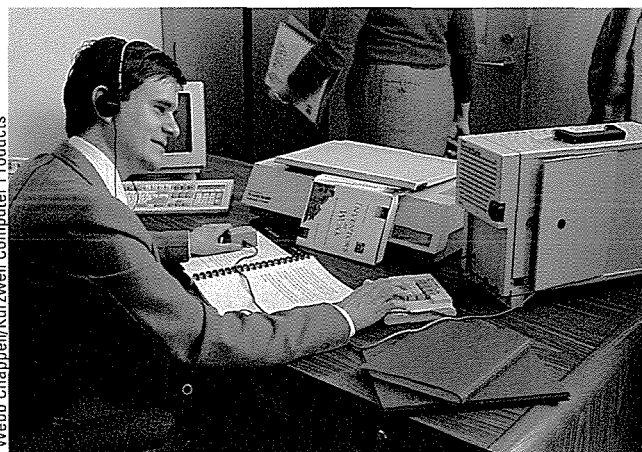
Reading Machine



Reading for the blind. By way of electronic signals, printed matter is converted into audible, synthesized speech.

pattern recognition is being put to good use in helping the blind.

Already, handheld ultrasonic and infrared scanners are available that will detect signals reflected off nearby objects. This acts as a kind of hi-tech white stick, telling the blind person if



Webb Chappell/Kurzweil Computer Products

there are any obstacles ahead as he or she walks down the street.

More sophisticated devices mount three detectors around spectacle frames. These produce an audio signal that the trained user can build up into a 3D image. Blind children who wear them from an early age can learn to recognize an object - a chair,

causing new problems for the blind.

However, the advent of the intelligent or 'smart' home where all the household appliances are plugged into one computer network offers hope. Each machine will have to have a socket where a blind person can plug in an adaptor so they can control the machine and get information out

ZEFA

Guide dogs have helped blind people move around safely for many years. The Japanese, however, have just developed a robotic guide dog (below) called Meldog that could take over.



MarkFranklin/Martin L Schneider Assoc. (USA)/Kurzweil Computer Products



via a speech synthesizer.

Passive tags - like those that are used to prevent shop-lifting from clothing stores - have been developed to help blind people with the London Underground system. It guides them to the gate and holds it open longer than for a sighted person.

say - from the sound it reflects.

Much of new technology is helping blind people. Computer speech synthesizers are now relatively cheap and Optical Character Recognition Systems - or OCRS - can now read a book, a document or a newspaper.



New problems

Touch screens, lift buttons that work by the proximity of the hand, flat keypads on phones and washing machines and banks without tellers - which are now open in Sweden - are

Just amazing!

EYE, EYE

THE HUMAN EYES CAN DISTINGUISH 10 MILLION DIFFERENT COLOURS - TWO-AND-A-HALF TIMES THE NUMBER THAT CAN BE DISTINGUISHED BY THE MOST ACCURATE SPECTROMETER.



Paul Raymond



ENERGY

ENERGY IS ESSENTIAL for modern life. We use it for heating and cooking, for all forms of transport and for industry to make things. For years each generation has used more energy than their parents. So new ways of generating energy have to be found.

A new source of energy, in the form of nuclear fission, has been developed to meet these needs, and now scientists worldwide are working on an even more ambitious programme to tame the process that powers the Sun. It is called nuclear fusion. In the Sun hydrogen atoms are fused together at temperatures around 15-20 million °C to form helium. For fusion on Earth we need to heat heavy forms of hydrogen – called deuterium and tritium – to about the same temperature.

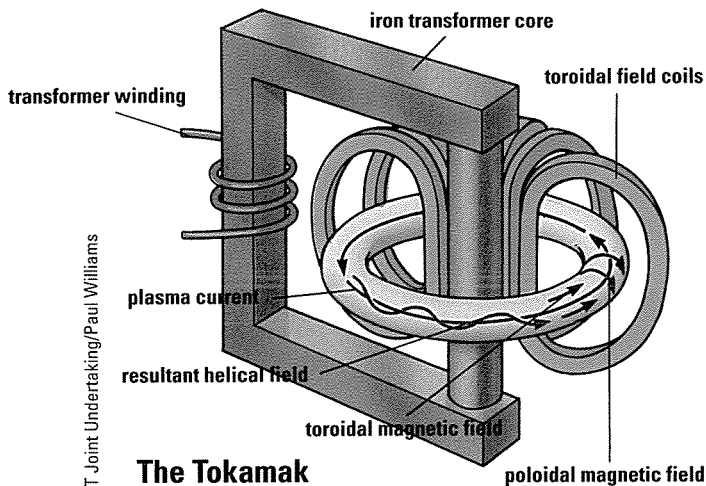
The torus, a giant ring-shaped vacuum vessel containing the hot plasma used in nuclear fusion, is made up of sections of a material called Inconel.

Nuclear power is so called because the energy comes from the nucleus of the atom. All matter is made up of atoms, each of which behaves as if it has a tiny nucleus surrounded by a cloud of particles called electrons. This is rather like the planets orbiting the Sun. The nucleus is made up of much larger particles called protons and neutrons. Different materials have different numbers of electrons. The power of the nucleus comes from the fact that matter can be converted directly to energy. By rearranging nuclei the plural of nucleus, the difference between the old and the new, can be released as pure energy.

Fission versus fusion

In fission, heavy nuclei, such as uranium, are split into smaller ones and a little extra energy is released. In fusion, lighter nuclei are joined together to form heavier ones. This is nuclear fusion. Nuclear fusion is different and more difficult to achieve from fission. The nuclei of small atoms are used in fission, but in fusion the energy released is used to heat the plasma.





The Tokamak

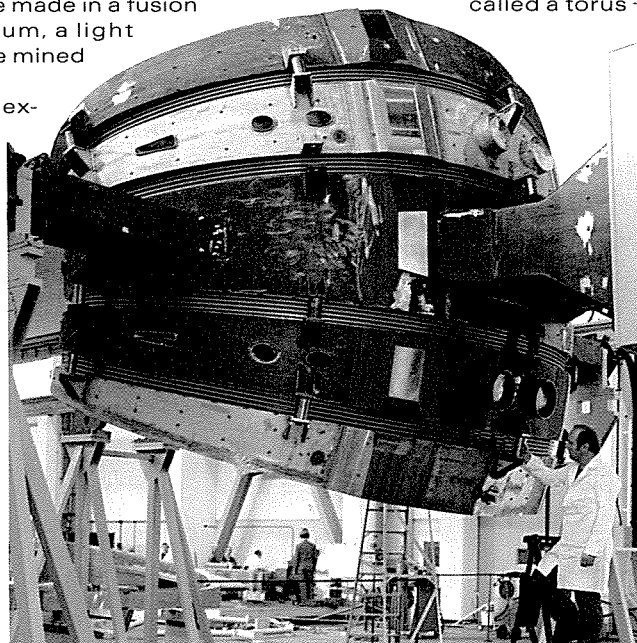
JET Joint Undertaking/Paul Williams

is produced. The easiest reaction for fusion on Earth is between deuterium and tritium nuclei, which must be heated to between 100 and 200 million° C. When deuterium and tritium nuclei fuse to form helium and a neutron, a small amount of their mass is converted into a very large amount of energy. There is enough deuterium in sea water to last for millions of years, while tritium can be made in a fusion reactor from lithium, a light metal which can be mined in many countries.

There are many experiments trying

Each constituent section of the vacuum vessel is made up of alternative thin bellows sections and thicker rigid sectors which are welded together.

Atoms of deuterium and tritium (isotopes of hydrogen) are fused together at millions of degrees Celsius to release energetic neutrons and helium.



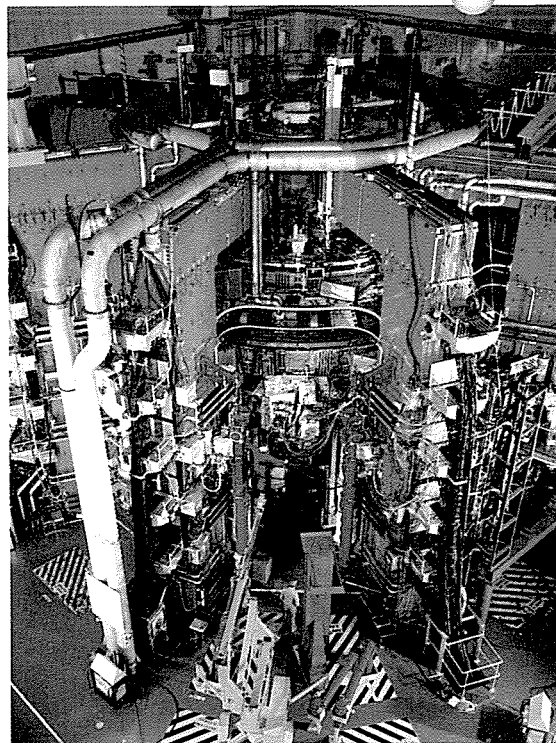
JET Joint Undertaking

which deuterium gas is heated to 300 million° C by large electric currents plus other heating methods. Such systems are similar to massive microwave ovens. At such temperatures the fuel is in the so-called plasma state – a sort of high-temperature gas. The plasma in JET is held away from the walls of the doughnut-shaped containing vessel – scientifically, called a torus –

In the Tokamak, the plasma is kept from the walls of the vacuum vessel by a system of magnetic fields and a current that is passed through the plasma.

Bird's eye view of the transformer structure – weighing 2,700 tonnes – which houses the 32 toroidal coils that confine the plasma.

Japanese, Russians and Americans. The experimental reactor stage will probably take 20 years and, assuming the demonstration reactor stage will take a similar time, then the first commercial reactor could start by the year 2040 – a time when coal, gas

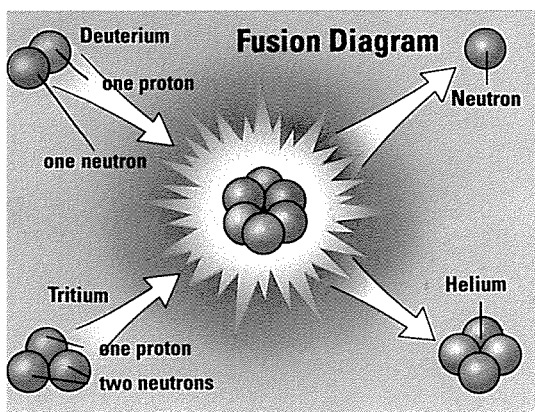


and oil will likely be in short supply.

The principal advantage of fusion is the vast amount of fuel available – enough for millions of years. The fuels are cheap and well distributed around the world. As there is only a small amount of fuel in the reactor at any given time, it will be a very safe reactor – unable to get out of control.

In 1989, two scientists claimed to have created 'cold' fusion at room temperatures in a test tube. But no one has been able to copy this and the future of fusion lies with high temperatures and massive equipment.

JET Joint Undertaking



JET Joint Undertaking/Paul Williams

by magnetic fields, made by the combination of a ring of electromagnets and the heating current.

The plasma with the right temperature and density must be contained by the magnetic 'cage' for the correct time. JET has achieved each of these values in separate experiments with deuterium fuel. With the correct deuterium-tritium fuel in JET almost as much fusion power would be generated as is needed to heat the plasma to these enormous temperatures.



Fusion fuel

The information learnt from JET and other fusion experiments will enable an experimental fusion reactor to be built. The design for one is already well advanced and could be started in a few years; it could be built by European countries alone or by a world-wide team – Europeans,

Just amazing!

FUEL FOR THOUGHT

YOU WOULD NEED ONLY 500 GM OF DEUTERIUM – THE RAW MATERIAL FOR NUCLEAR FUSION FOUND IN SEA WATER – TO PRODUCE AS MUCH ENERGY AS 1,000 TONNES OF COAL.



Paul Raymonde



FORWARD

THE DEATH OF THE TEACHER has long been predicted as computers invade the classroom. However, hand-in-hand with technology, teachers are finding themselves a new role in the class of 2020.

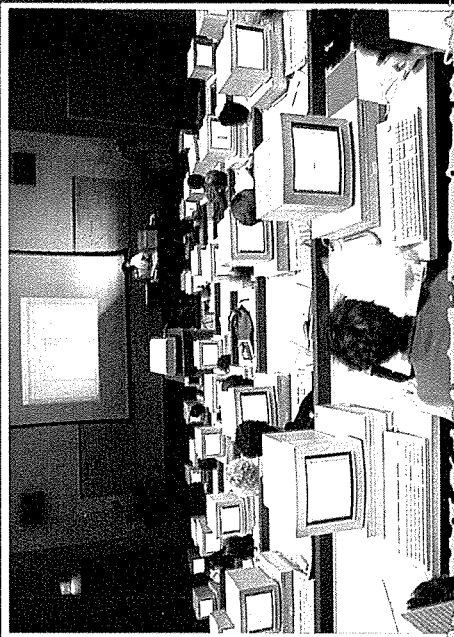
Interactive video on CD TV is going to take over much of modern education. At the heart of interactive video is the video disc, a 30 cm version of the audio CD which can hold up to 57,000 television pictures. These are viewed on a laservision player, which is essentially a larger version of the

standard CD player, that plugs into a television monitor.

This laservision player is put under the control of a powerful computer. The program, via the computer, displays messages on the screen asking the pupils questions. Depending on their reply, the computer cues a sequence of pictures from the laser disc.

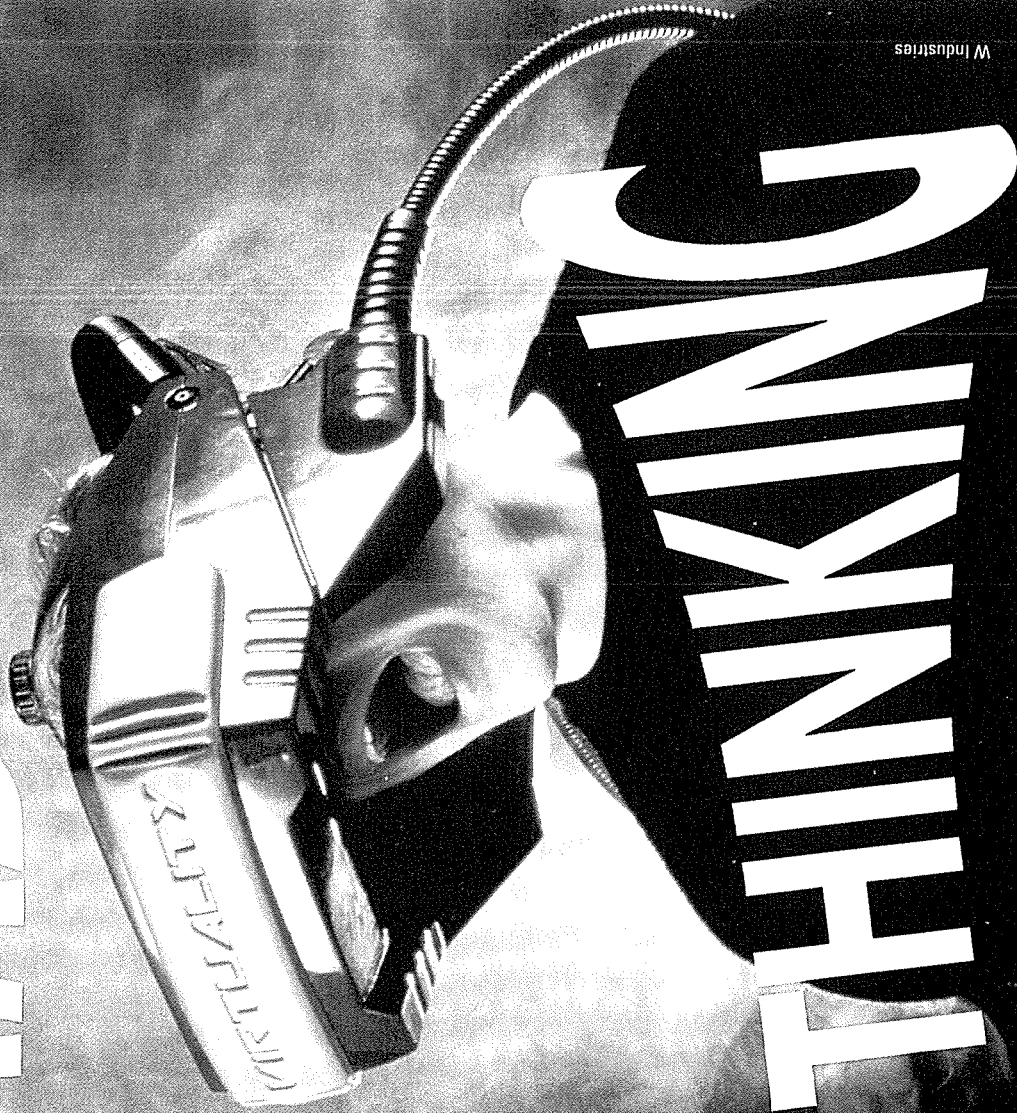
Graphics overlay

As the same screen is shared by the computer and the laservision player, computer graphics can be overlaid on the 'real' television pictures from the



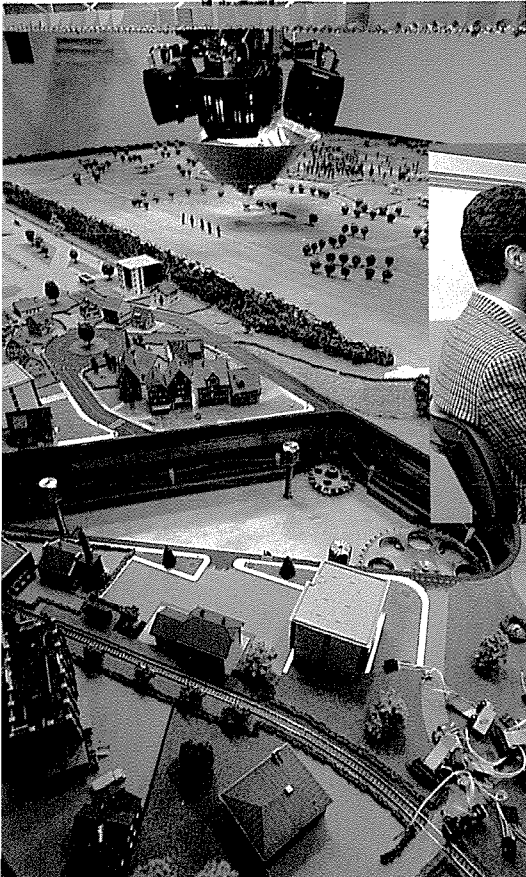
Hank Morgan/Science Photo Library

'Virtual reality' gives the user the illusion of being in an interactive world projected inside special goggles. This would allow a student to perform a dangerous experiment without risk. Students can have lessons and tutorial debates (left) via computer networks.



THINKING





It is much safer to teach people using a simulator which directs a camera around a model. It can be used to teach people to fly, or drive trains (below).



Pitchal/Jerrican

their own lessons, accessing the pictures on the laser disc and tailoring them for their own pupils.

Hook up

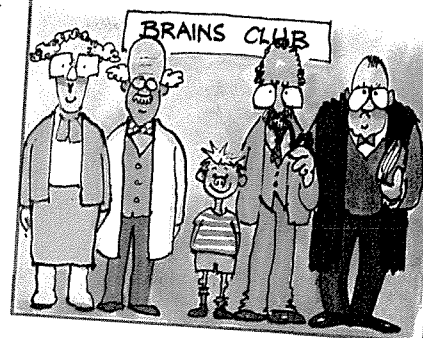
Another device that could come into its own is 'virtual reality'. Hooking up special projection goggles and earphones to a dataglove - which records electronically the movements of the hand - or a datasuit - which does the same thing for the whole body - via a powerful computer, it is possible to give the sensation that the operator is inside a realistic computer-generated world.

The dataglove or datasuit allows the operator to interact with this fantastic environment. This would mean, for example, that a science student could perform dangerous experiments in complete safety, or a medical student could practise surgery without risking the life of a patient.

Just amazing!

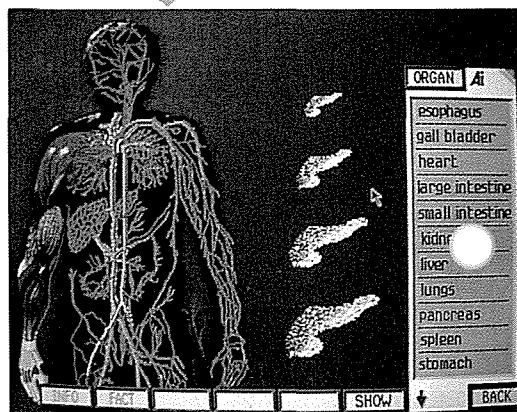
TEENAGE MUTANT HERO TUTORS

GERMAN GENIUS CARL WITTE OF LOCHAU GOT HIS PHD IN MATHEMATICS WHEN HE WAS JUST 12 YEARS OLD.



Paul Raymond

Body building - interactive video-style. The student learns where the vital organs go without dissecting a corpse.



laservision. This allows the viewer to measure things on screen and perform surrogate scientific experiments.

CDTV players have a slot for a 'smart card' in them. This means that lessons could be tailored to individual children and their progress recorded electronically on the card.

Teachers will also be able to write

INTO THE FUTURE

EDUCATION WITHOUT END



▲ As the pace of progress quickens, education will last the whole of your life. But with interactive video at home you will not have to go back to school.

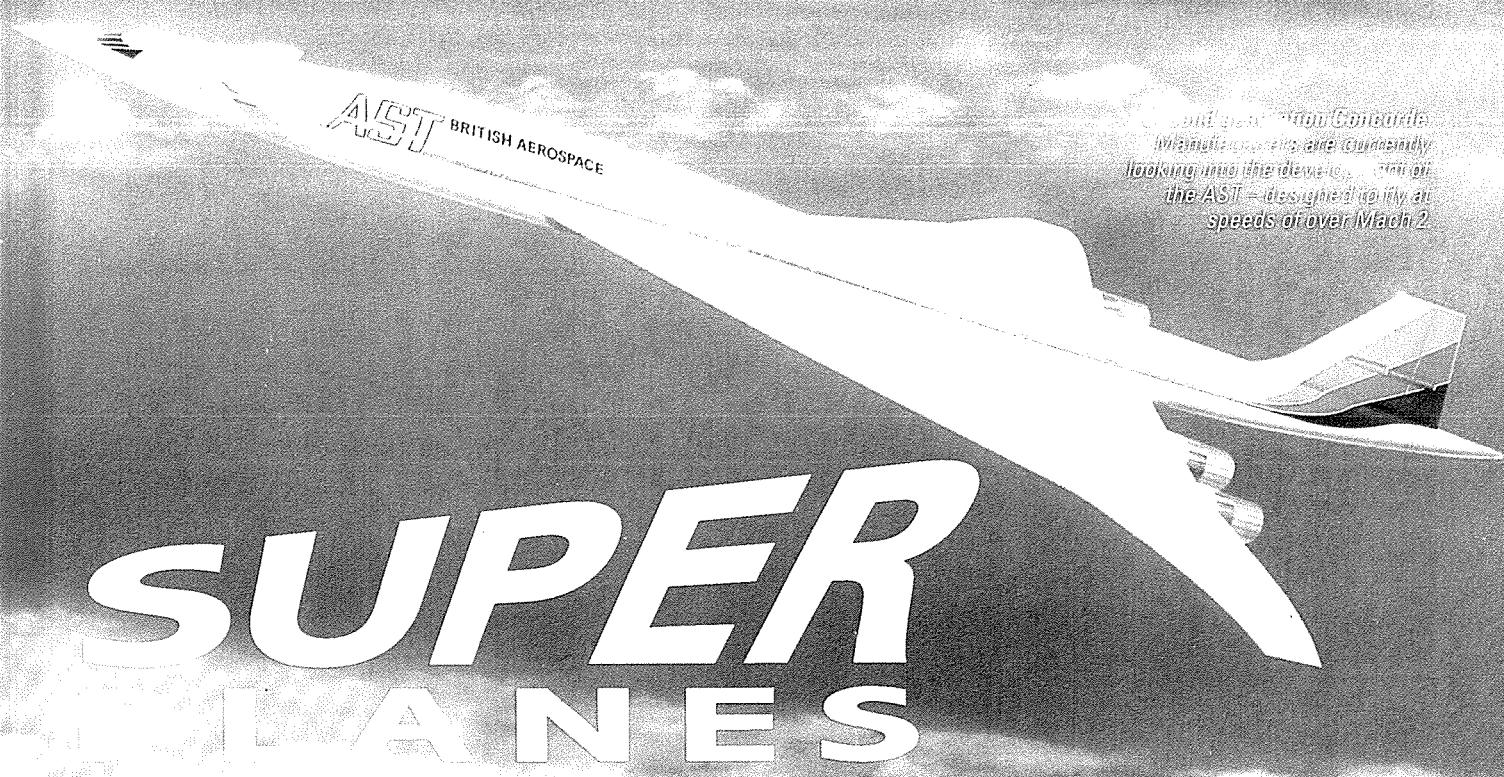
▲ Extremely specialized subjects, which only an handful of people in the world are studying, will be taught via teleconferences.

▲ You will not have to memorize anything. You will simply develop your own customized computer systems to solve problems and access information.

British Nuclear Forum

Joe Lawrence





And just like Concorde, the new superplanes are constantly looking into the future. This is the AST - designed to fly at speeds of over Mach 2

SUPER PLANES

Rex Features

WITH HARDLY A SENSATION at all, the huge jetliner crosses the threshold from sub- to supersonic speed and accelerates to its cruising speed of Mach 2.5 - 2,650 km/h. The 300 passengers aboard relax into their seats knowing that their non-stop flight from Los Angeles to Sydney will last a mere five and a half hours. This is a glimpse of air travel in the near future.

Having been in commercial service since January 1976, the world's first supersonic passenger aircraft, Concorde, has not been particularly successful. Compared with today's efficient subsonic planes, it is noisy, burns a lot of fuel, especially when it has to fly at sub-sonic speeds, and its ticket prices are much higher.

Indeed, the experience of Concorde has put a lot of aeroplane manufacturers off the idea of supersonic airliners. But now there is a growing demand in the long-range market and technical advances in high temperature structural materials and variable-cycle engine technology, have been made. A number of companies, including Boeing, British Aerospace and Aérospatiale of France, are working on the design of new supersonic planes. Boeing call their potential airplane an HSCT (High Speed Civil Transport) and British Aerospace call theirs the AST (Advanced Supersonic Transport). Both

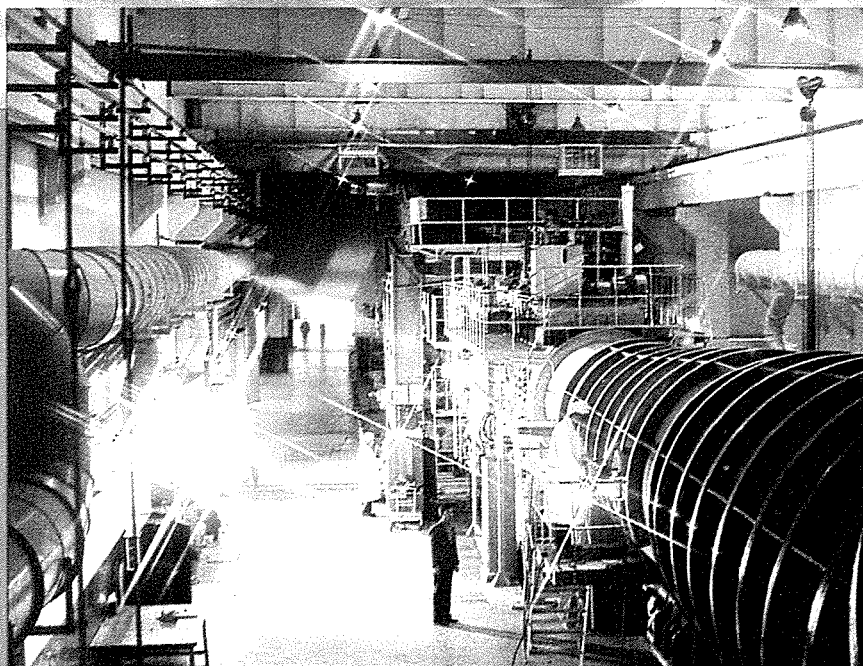


PHOTO BY BROWN

Xinhua/Gamme/Grant Spangner Pictures

are planned to take to the air by the year 2005.

Currently Concorde can carry just over 100 passengers at Mach 2 and has a range of 6,500 km. The new generation of superplanes would carry 250 to 300 passengers at Mach 2.5 up to 9,300 km.

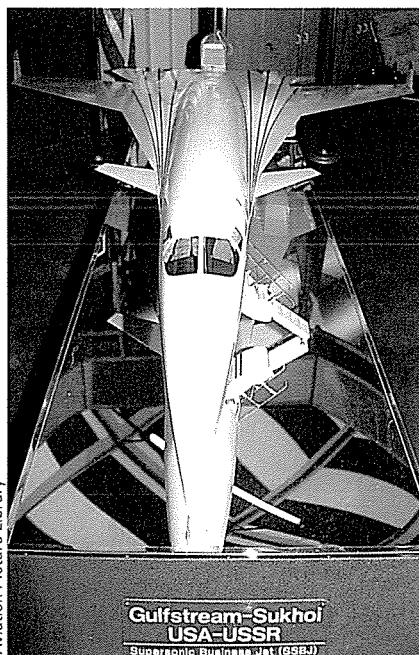
Advanced materials

One of the research programmes at Boeing is looking at composite structural materials and advanced metals capable of coping with high temperatures generated by air friction on the outer skin of the new superplane. Materials will have to survive

Wind tunnels are essential to determine the aerodynamics of a high speed plane.

temperatures of 175° to 205° C. This is one of the key areas because of the need for efficient, lightweight structures combined with resistance to high temperatures. Boeing is looking at thermo-plastic resins and improved thermo-setting matrixes such as toughened bismaleimides. Metals will only be used in areas requiring extra strength, such as the rear spars of the wing which carries the engines, and in areas where there might be erosion,





Travelling to a meeting at well over twice the speed of sound will soon become reality with this jet capable of 2,450 mph.

such as the front of the wings.

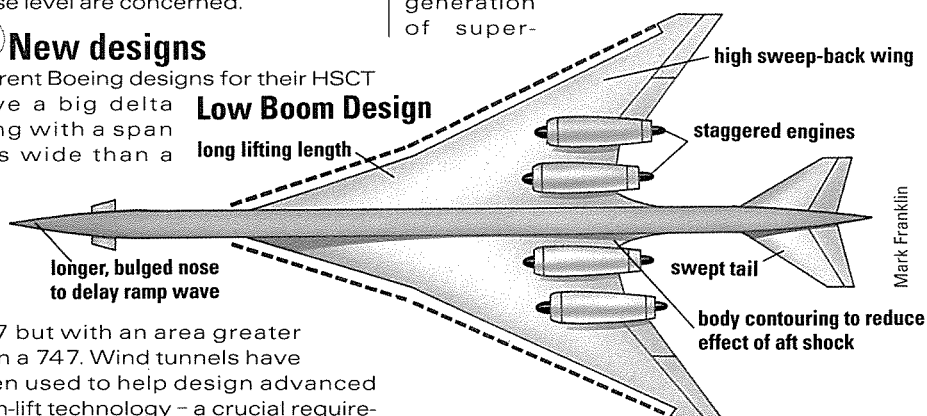
The aeroplane of the future will have to be economical with a typical long-range mix of first, business and tourist-class passengers. But it will also have to be comparable to the subsonic planes of the day as far as its effects on the environment and its noise level are concerned.



New designs

Current Boeing designs for their HSCT have a big delta wing with a span less wide than a

Low Boom Design



Mark Franklin

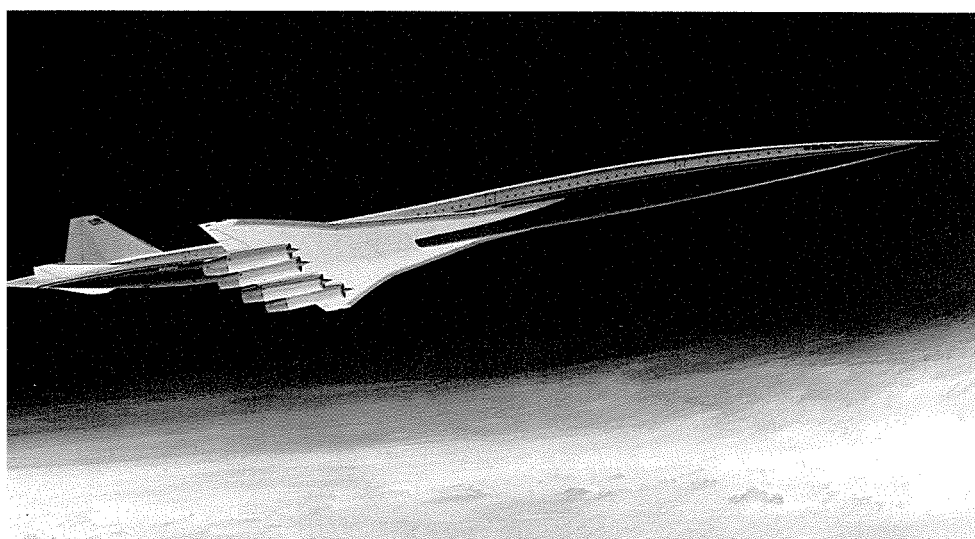
767 but with an area greater than a 747. Wind tunnels have been used to help design advanced high-lift technology – a crucial requirement in solving the noise problem.

Efficient high-lift devices help minimize engine thrust and noise on take-off and landing. In this respect, one Boeing study is aimed at a system that automatically adjusts the angle of

Reducing the sonic boom is one of the major challenges that designers of tomorrow's high-speed planes face.

planes will be designed to cruise at 1,000 km/h before going supersonic over the sea. This is still faster than conventional subsonic planes currently cruise.

Researchers are looking into ways to minimize the effect of the sonic boom, but early research has shown that the shape which would be needed to make the plane less 'boomy' would make it unacceptably heavier and noisier at take-off.

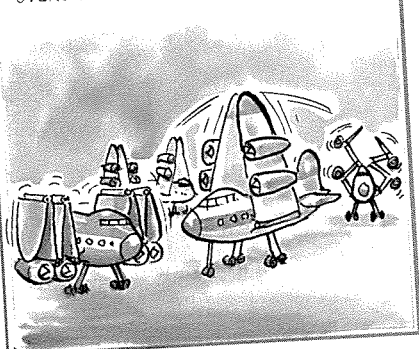


Boeing

Just amazing!

IN THE FOLD

BOEING'S NEW GENERATION OF SUPER JUMBOS WILL HAVE FOLDING WINGS SO THAT THEY CAN FIT INTO EXISTING OVERCROWDED AIRPORTS



Paul Raymond

The design characteristics of the new supersonic transports are crucial in order to survive in a competitive environment.

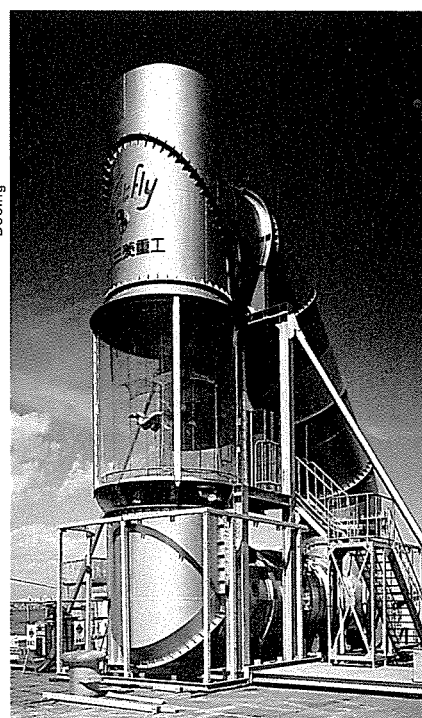
the flaps – the trailing edges of the wing – to get the best lift as the plane climbs after take off.



Variable engines

Engines will have to cope efficiently and quietly with both subsonic speeds and supersonic flight. To this end, variable-cycle engines are being investigated. These act like a quiet turbofan engine during take off and landing, but they convert into an efficient turbojet at high altitude for supersonic flight.

Several approaches to this are being tried. These include the variable-cycle turbine bypass turbojet from Pratt & Whitney, the variable-cycle turbojet/turbofan from General Electric,



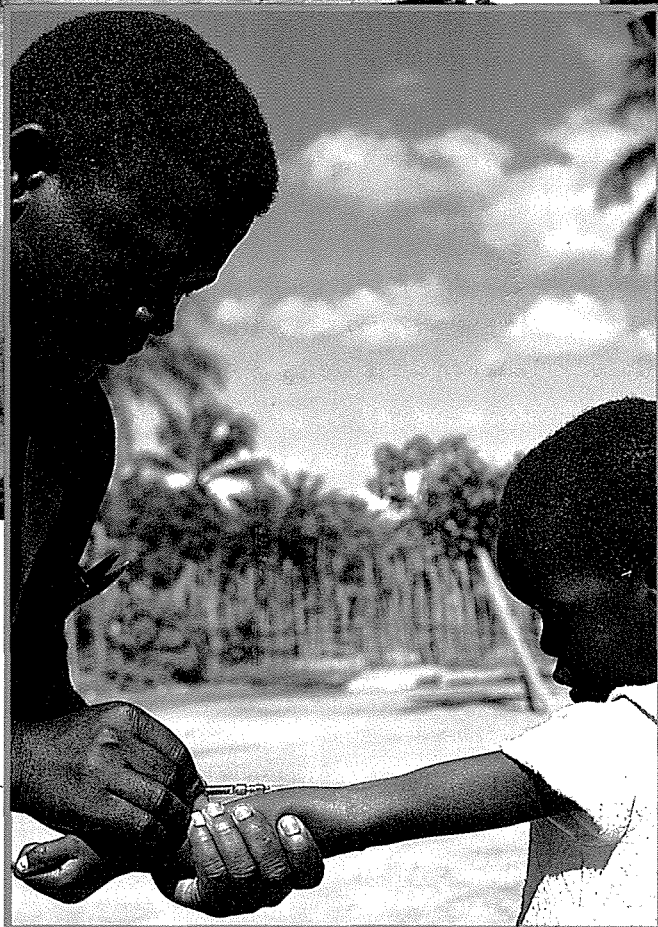
K. Kurita/Gamma/Frank Spooner Pictures

Unlike skydivers, supersonic plane passengers of the future won't have to undergo the free fall test before starting their journey!





PESTILENCE



Hutchison Library

***Poor housing** and contaminated water aid the spread of disease, particularly in Third World countries.*

***Malnourished** children in the Third World are still vulnerable to disease, despite widespread immunization programmes.*



THE BLACK DEATH KILLED some 75 million people in just four years as it swept across Asia and Europe. That was in the 14th century, though.

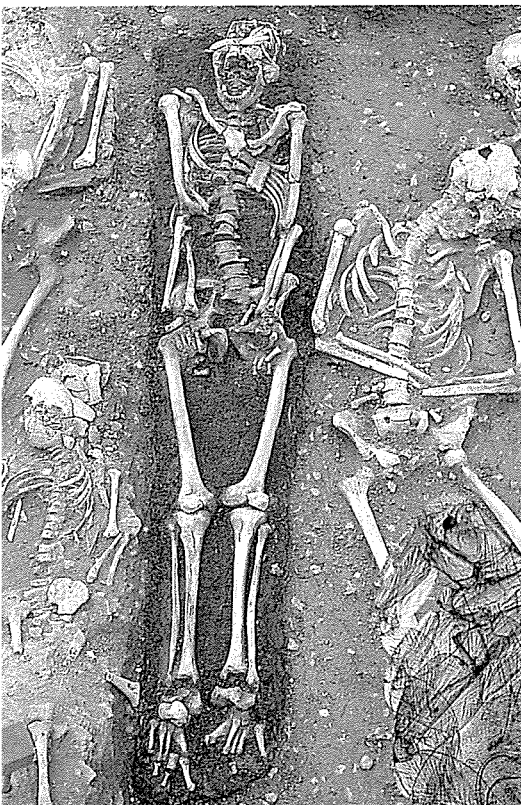
Since then medical science has progressed a great deal. But humankind is still plagued with epidemics of killer diseases that seem almost unstoppable.



Child killer

Measles is one of the world's major killers. Although it is considered a fairly trivial childhood disease in





Museum of London
Bubonic plague is spread by rat fleas (inset right). The disease has been eradicated from Europe but still breaks out in epidemic proportions in Third World countries.

J. Burbidge/SPL

developed countries, it kills more than two million children every year, mainly in the developing world. It also causes deafness, blindness and brain damage as well as severe malnutrition which lowers resistance to other diseases.

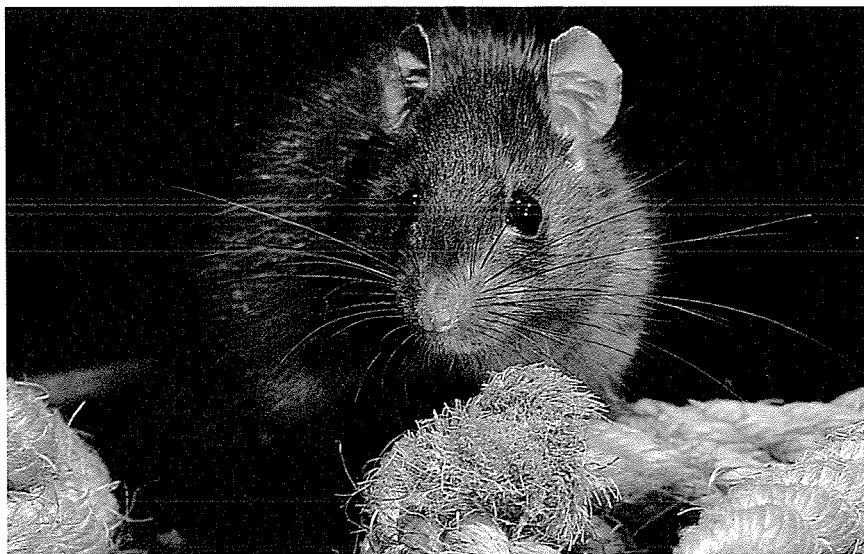
Eradiation

The World Health Organization have scheduled measles for eradication. But some experts think that they are being over-optimistic. It is a highly contagious disease that can exist in even a tiny unprotected population. In the United States, for example, 97 per cent of people have been inoculated against measles, but despite this it still spreads.

Even if 100 per cent of people had been inoculated, it would probably still not be eradicated as the vaccine is only 95 per cent effective. It is thought that measles could probably exist in just the 5 per cent of people who were unprotected, especially as it can be spread through people who do not come down with the disease and do not show any symptoms.

Subclinical cases

So far, only one disease has been completely eradicated – smallpox. But unlike other diseases, smallpox cannot be passed through animals and



Jane Burton/Bruce Coleman Ltd

The 'plague rats' that spread the Black Death in Europe in the Middle Ages were largely black rats. They are now extremely rare in Europe.

does not live for any length of time outside the human body. It has to be passed through close contact being human beings. And there are no subclinical cases – that is, carriers who have the disease but do not show symptoms. This explains why smallpox could be eradicated by 'strategic containment'.



Stopping the spread

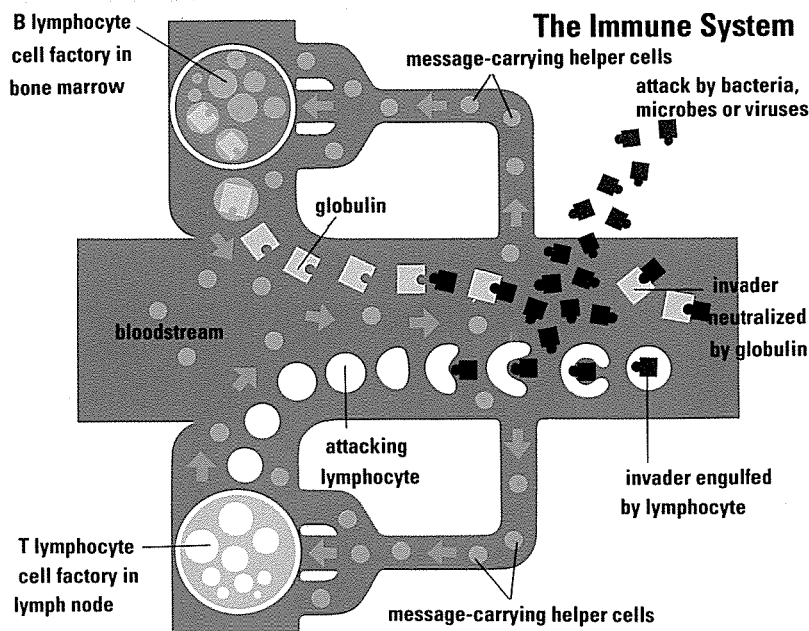
When a case occurred, it was easily identified and all the victim's contacts could be vaccinated. This prevented the disease from spreading. Slowly, the disease could be isolated into tiny pockets and, eventually, eradicated.

Another advantage was that the vaccine was easy to administer – it

could be given by a simple scratch on the skin, which meant that doctors and nurses did not have to go to remote areas to start immunization programmes. Also, only one dose was needed to give complete protection while most diseases, like

IMMUNITY

The human body's ability to resist disease depends on lymphocytes in the bloodstream. These make the antibodies that protect us from attack by viruses, bacteria and other microbes. Lymphocytes form about one-third of the white cells in our blood and are entirely concerned with immunity. One group – B lymphocytes – are made in the bone marrow. The other – T lymphocytes – are processed in the lymph glands where they become specialized in identifying and rejecting invading bacteria. The body's immune systems can be stimulated by injecting the virus of a similar – but harmless – disease or the dead virus of the disease itself.



John Hutchinson

BSE – THE DANGERS OF MAD COW DISEASE

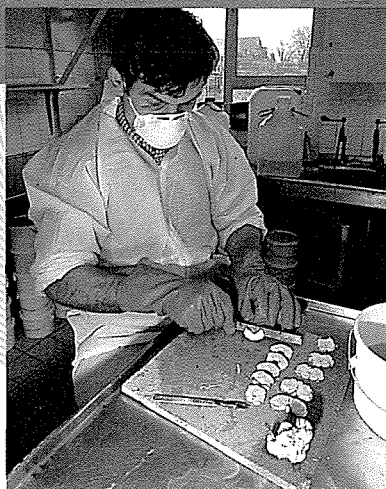


below.) The disease has crossed over from sheep to cows because sheep's offal and waste meat has been processed to make food for cows. There is no evidence that BSE will cross into humans who eat meat from infected cows. For many years, there was little regulation of the use of meat from infected sheep. However, a danger does exist and regulations have been introduced preventing the use of the nerve tissue of infected animals. These measures have contained the disease, which is now almost eradicated.

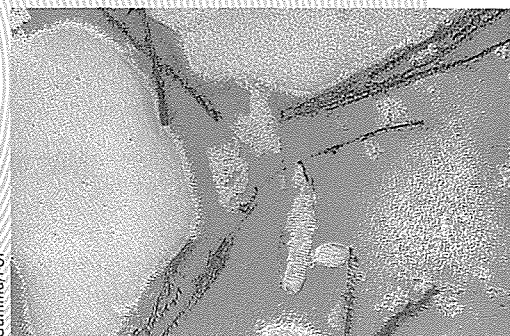
EM Unit, CVL, Weybridge/SPL

Rex Features

Bovine spongiform encephalopathy – or mad cow disease – first occurred in Britain in 1986 and appears to be related to the disease scrapie that has affected sheep for around 250 years. It makes the animal unsteady on its feet, nervous and aggressive. (Sections of infected sheep's brains are shown right, and magnified organisms of the virus,



Gamma/FSP



measles, require a course of three doses over several weeks.

What's more, smallpox vaccine does not have to be kept at a low temperature or in any special conditions like other vaccines – it can be carried easily and administered anywhere it is needed.

**The last death**

The last naturally occurring case of smallpox was recorded in Somalia in 1977 and it has now been successfully eradicated. However, a laboratory worker was killed in Britain more recently. The virus is still kept in laboratories in case it was ever used as a weapon of

war. If some of the virus were to escape, it would spread fast because people have lost any natural immunity. However, doctors are confident that they could quickly bring any outbreak under control by the same method of strategic containment.

**The polio virus**

The World Health Organization has an Extended Programme of Immunization which aims to eradicate several other diseases. One of them is the polio virus which is fatal for 10 per cent of its victims and leaves many of the others with varying degrees of muscle paralysis.

The virus is fairly difficult to identify as it can pass through humans without them showing the symptoms. It can also survive in, say, a cold dark sewer for four to five months, and thrives in places with poor sanitation and contaminated water supplies. One in ten million get polio from the polio vaccine itself.

**Tetanus vaccine**

Tetanus kills a million babies every year. Many of them are infected through the umbilical cord soon after birth and some 85 per cent of the babies that contract the disease die. A course of tetanus vaccine has to be

Leprosy, also known as Hansen's disease, is a chronic inflammatory disease that can be controlled with sulphone drugs, but cannot be cured.

administered – and boosters given at regular intervals throughout life. However, the virus can also survive well outside the human body in the environment.

**Brain damage**

Whooping cough kills 750,000 children every year. Violent and prolonged coughing fits can cause exhaustion and even permanent brain damage. Even in developed countries some parents refuse to have their children concerned immunized because of the slight danger – one in 100,000 – of brain damage caused by the vaccine.

Tuberculosis – or TB – is still a major cause of death and disability in developing countries. Very young children

Just amazing!**GERMS IN SPACE**

A MOON PROBE LOCATED BY APOLLO ASTRONAUTS HAD BACTERIA CLINGING TO IT, STILL ALIVE AFTER 21 YEARS ON THE MOON.

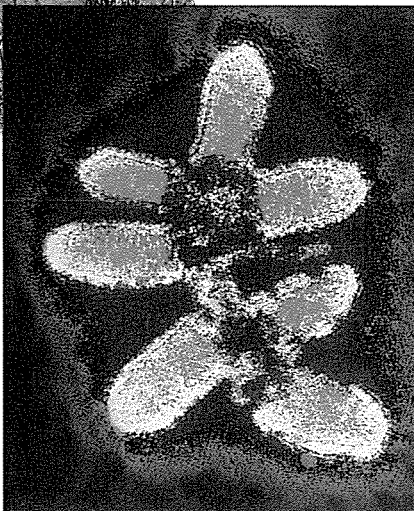


Paul Raymond





The rabies virus (pictured magnified, below) is an acute and usually fatal disease that can be transmitted to Man by the bite of an infected animal, typically a wild dog (left), wolf or cat.



are particularly susceptible to severe forms, such as TB of the spine which can cause paralysis of all the limbs. Mental retardation is another consequence of the disease.

Diphtheria can cause death or very serious illness with severe blocking of breathing passages. It also produces toxins that can permanently damage the heart and nervous system.

Immunization

Both TB and diphtheria have been virtually wiped out in the developed world. But in the Third World, where malnourished children are particularly vulnerable, even the current extended immunization programme is making little impact. Some 80 other diseases are scheduled for eradication by the World Health Organization.

The problem is that immunization is not enough. It is almost impossible to stamp out disease in countries where the water supply is contaminated, housing is poor and where there is not enough money to provide

a hospital bed and even the simplest of health care. Immunization alone cannot stamp out disease in places where people do not have soap and water to wash with.

AIDS in Africa

AIDS is spreading through Africa for these reasons. Although it is not a very contagious disease – it does not pass from one person to another easily – it is new and the body has no natural resistance. Indeed, the HIV

virus actually attacks the immune system itself.

Malnutrition and other conditions help the spread of the disease. It is estimated that some 3 million people are affected.

New vaccine

There is, as yet, no cure for AIDS, although a new vaccine called rgp 160 has been tested safely on healthy patients at various US research centres. Rgp 160 works in the same way as other vaccines – by imitating the virus it stimulates the production of disease-fighting antibodies.

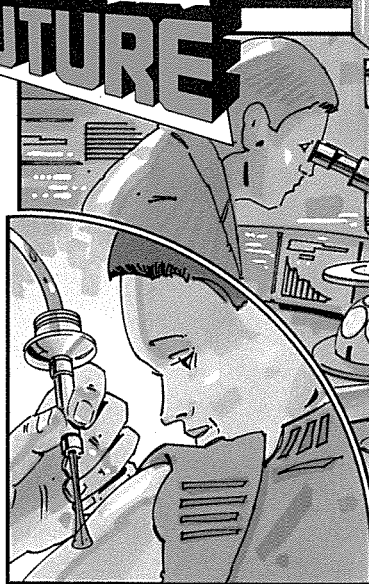
Although there are numerous sub-clinical cases in AIDS, the HIV virus thought to be responsible does not survive at all outside the body. Transmission rates are low, so there is hope that the AIDS virus can be defeated in due course.



Polio attacks thousands of children every year, killing one in ten of its victims and leaving many paralysed.

INTO THE FUTURE

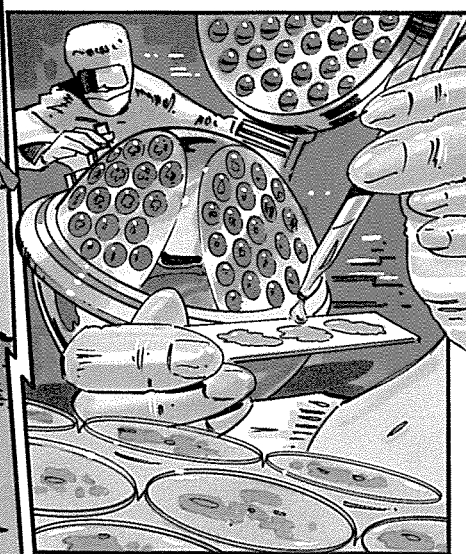
THE DANGER OF HEALTH



▲ It is conceivable that all known diseases will be wiped out. The viruses and bacteria that caused them would be tracked down and eradicated.



▲ This would leave humankind seriously vulnerable. With no natural immunity, a disease escaping from a laboratory or from Space would spread rapidly.



▲ But genetic engineering techniques would produce serums to cure the infected. And immunization and hygiene would bring the disease under control.

